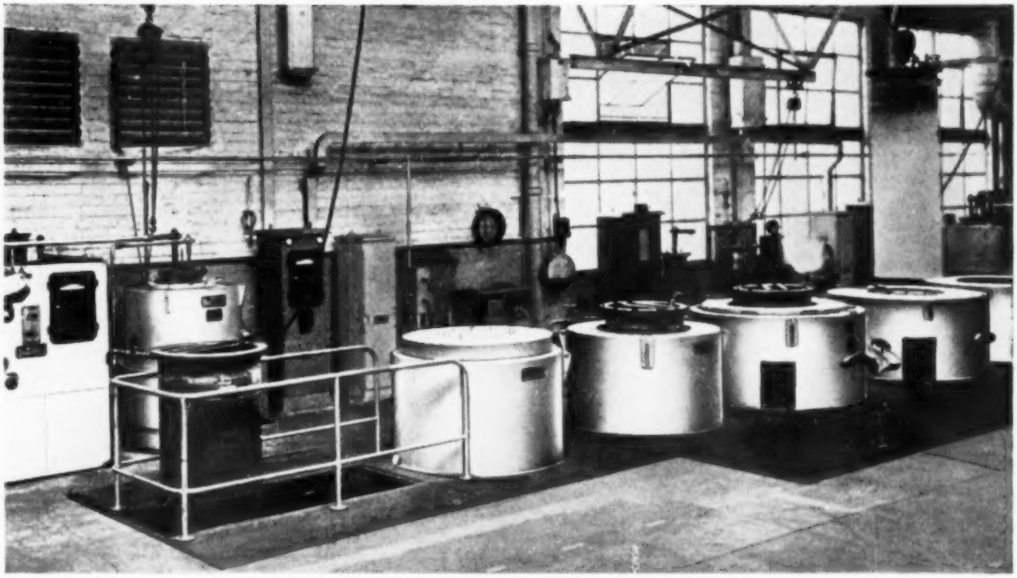
metal treatment and Drop Forging

Vol. 25 : No. 152 MAY, 1958 Price 2/6



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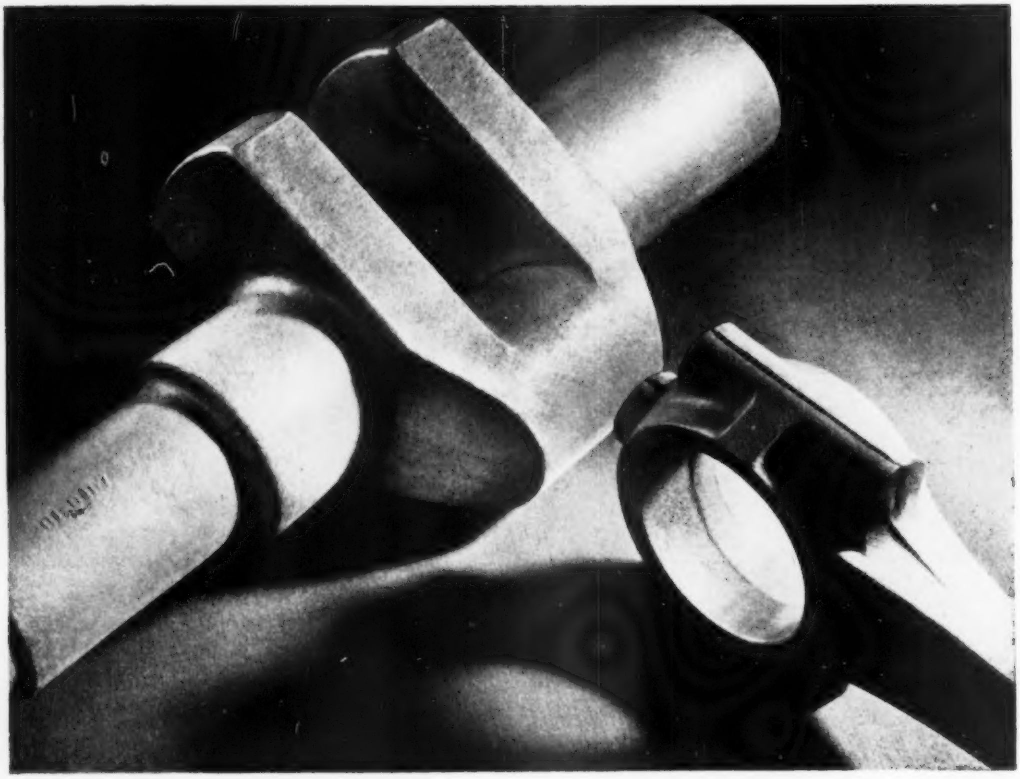

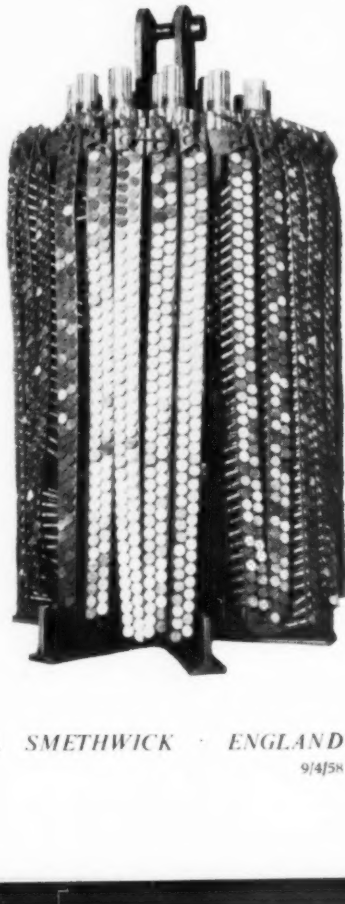

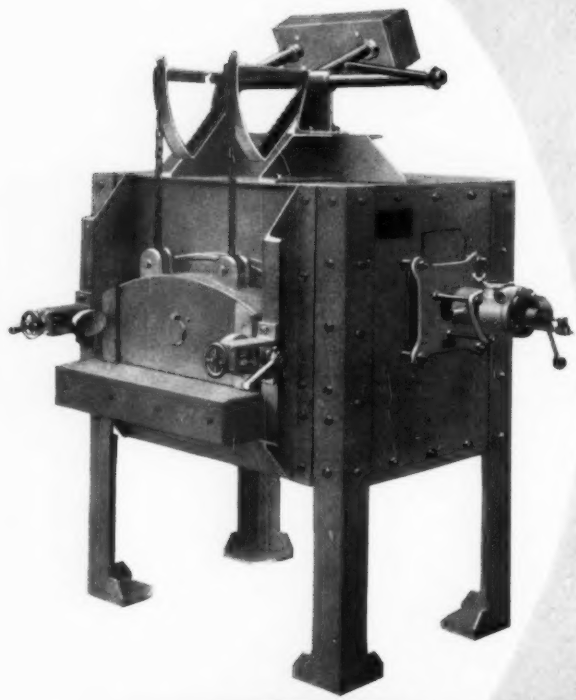

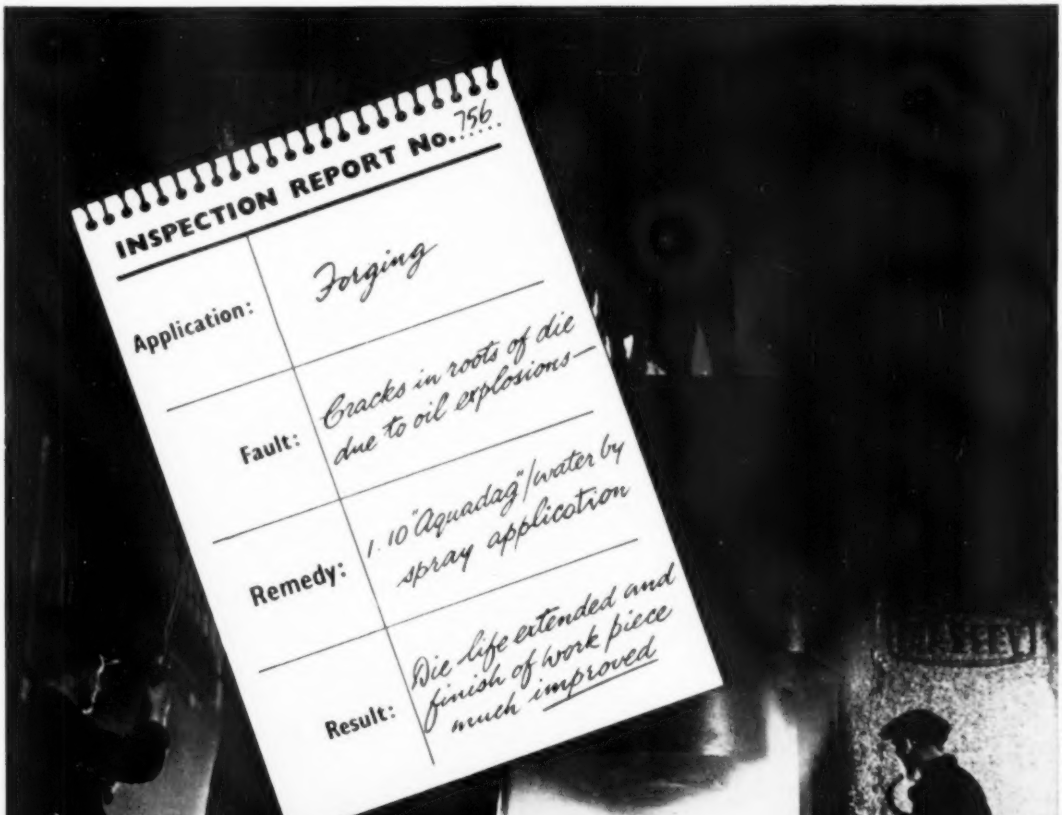
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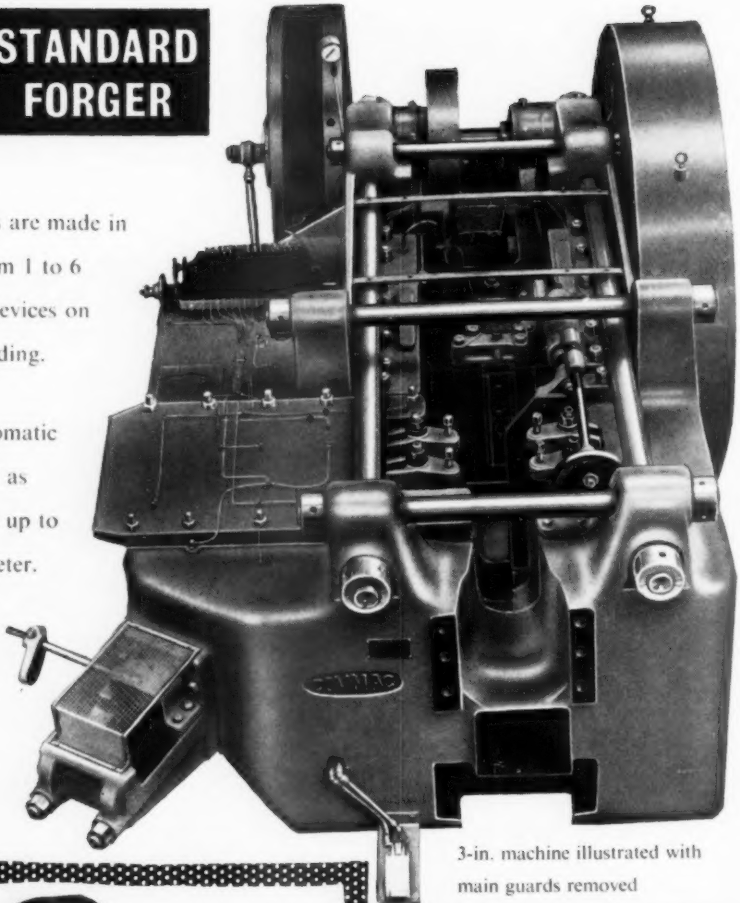
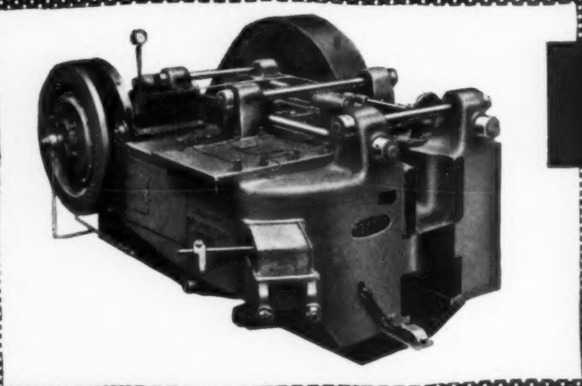


3-in. machine illustrated with main guards removed



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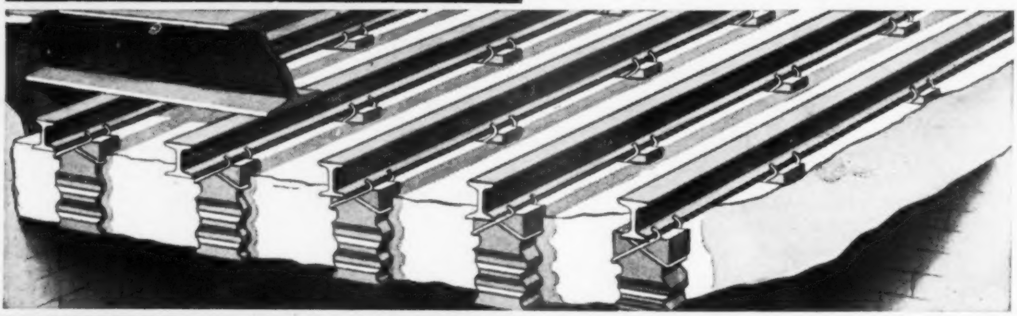

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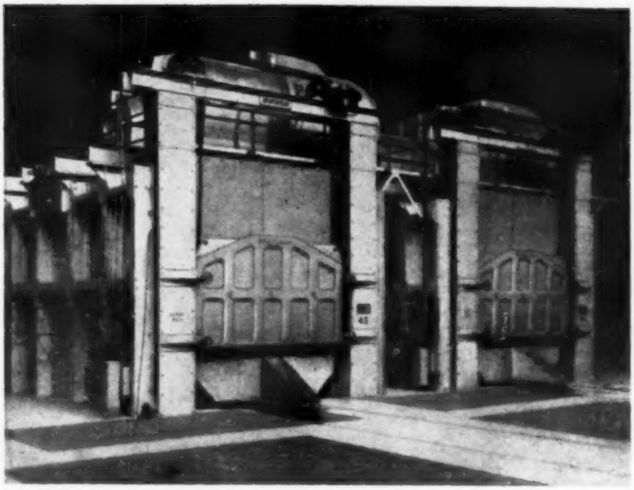

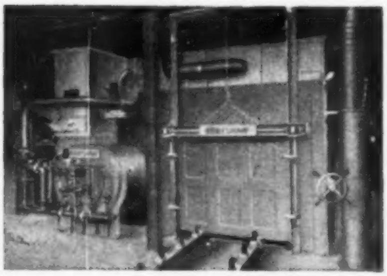

May 1958

Vol 25, No 152

metal treatment

and Drop Forging

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Official organ of the NATIONAL ASSOCIATION OF DROP FORGERS AND STAMPERS

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Grove Hill House, 245 Grove Lane Handsworth, Birmingham 20

Telephone NORthern 3311-3

Telegrams Asdroforge, Birmingham

Published on the 15th of each month by INDUSTRIAL NEWSPAPERS LIMITED

John Adam House
17-19 John Adam Street
Adelphi, London W C 2

Telephone TRAfalgar 6171 (10 lines)

Telegrams Zacatecas, Rand, London

Subscription Terms Home and Overseas 30s per annum prepayable Single copies 2s 6d (2s 10d post free)

CONTENTS

This journal is devoted to metals—ferrous and non-ferrous—their manufacture, properties, heat treatment, manipulation, testing and protection, with research work and development in all these fields

Technical authorship

AN exploratory committee, set up by the City and Guilds of London Institute under the chairmanship of Major-General Sir E. Bertram Rowcroft, has recommended that courses and examinations in technical authorship should be arranged by the Institute. Such a scheme has now been prepared, and we understand that syllabuses and examination arrangements will shortly be made available, so that the subject of technical writing and editorship may be taught at technical colleges, and the students taking such a course sit for a recognized diploma. Clearly, such a departure is one which touches us closely, and it behoves us to think deeply regarding the pros and cons of such an arrangement.

Considering the possible advantages first, there is no doubt that the average standard of English achieved by the technically educated in this country does tend all too often to be deplorably low. Time and again the complaint is made that the young technologist falls down very badly when he has to put together a reasonably coherent and readable report. Even elementary mistakes in spelling and grammar find their way into pages where least expected. Any steps taken to remedy such a state of affairs cannot do anything but good.

But are, in fact, the proposals now put forward by the City and Guilds Institute likely—or even intended—to improve matters in this respect? The statement published in the Institute's ' broadsheet ' (No 12, April, 1958) speaks of ' those who wish to train as technical authors . . .,' implying that the future will witness the emergence of the ' technical author ' as a specialist whose job is primarily writing on technical matters (presumably for the technical press), whether or not he is himself engaged in, or even remotely connected with, the technical subjects he describes. Fortunately, the committee has recognized this obvious danger, and therefore principals of technical colleges are asked to satisfy themselves as to the students' ' technical competence ' before admitting them to the course; but the subject of technology is so vast that we cannot help wondering whether this is enough.

No, all in all, we cannot view the new City and Guilds course with much favour. Technical writing is not a specialized subject which can be mastered by a course of part-time instruction, even though this amounts to at least 600 hours. Good technical writing stems from a combination of two factors—an intimate and practical knowledge of the technical subject being dealt with, and an ability to handle the English language. The first is an expertise which comes from prolonged instruction and experience; the second is an art which can only be perfected by practice based on a thorough basic grounding—*a grounding which should be imparted during the years at school.*

We do not believe that good technical writing will result from the new City and Guilds course. It savours rather too much of those ' schools ' which claim to teach one how to write advertising copy or scripts for television. These establishments do no great harm, since nobody expects popular advertisements to tell the strict truth or imagines that ' soap operas ' will put the ' Old Vic ' out of business. The same is not true of technical writing, where it is of the first importance that the technical content be absolutely above suspicion, whether or not it be expressed in the best way. Better technical authorship will, surely, be far more certainly achieved by ensuring that good technologists are taught early in their training to write good English. The rest will follow automatically.

Instrumentation for iron and steel

The Instruments and Electronics Automation Exhibition, held at Olympia last month, was again held concurrently with a conference on the use of instrumentation in many fields. Included among the papers was a review of iron and steel works instrumentation given by Mr B. O. Smith, M Sc, A Inst P, of B I S R A

INTRODUCING THE SPEAKER, the chairman, Mr L. S. Yoxall, said that as long ago as 1921 he had appreciated how the iron and steel industry was ready to co-operate with modern methods of automatic control and measurement; the industry had been very receptive, ready to listen to and install any such methods which could help it.

Mr Smith began by saying it was convenient to consider the processes of an integrated steel works in four main groups, characterized by the nature of the material passing through each group. The first two groups were common to all works, but at later stages of the third and in all of the fourth group there were considerable differences according to the nature of the end product.

First, the basic raw materials, coal and iron ore, were processes in basically granular form until entering the blast furnace. From that point, ironmaking, steelmaking and ingot casting were all centred round liquid metal at temperatures about 1,400—1,600°C, at handling capacities of 10 or even 100 tons at a time. The third stage took the newly cast ingot, which commonly weighed between 7 and 12 tons at temperatures between 900°C and 1,200°C, through stages of hot rolling interspersed with reheating where necessary. Where appropriate to the final product, he said, this stage ended with hot coils or cut lengths. The last group, he continued, was concerned with cold processing and may include such widely different plants as a tinning line or wire drawing shop.

The instrumentation and control of those processes, he went on, had not developed uniformly, although great progress had been made in the last few decades in certain directions. In some cases plant had been fully instrumented—in fact, one might even commit the heresy of suggesting over-instrumented !—while the process within that plant still depended on the skill and experience of the operator. That could be illustrated by considering the open-hearth steelmaking furnace and the slab reheating furnace. Steelmaking, he said, was a high-temperature oxidation process in which unwanted constituents, such as silicon, phosphorus and carbon were removed from the hot metal. The open-hearth furnace, he pointed out, was a brick-lined chamber, perhaps 60 by 15 by 10 ft, holding a charge of 100—200 tons. It may be gas- or oil-fired, and was of the regenerative type, reversing in operation approximately every 15 min.

Furnace control

One of the critical variables of furnace operation was roof temperature and minimum efficient operation temperature was small—about 50°C. Roof temperature was normally measured by one or more radiation pyrometers, and regulated fuel flow. Two ratio instruments set, from the fuel flow, the correct flow of atomizing steam to the burner and of combustion air to the regenerators or checkers which had been heated on the previous pass by the outgoing waste gas. One of the interesting problems of temperature measurement arose from the fact that the furnace roof was not at a uniform temperature, and the temperature distribution changed with each furnace reversal. This had been partially met either by the siting of two pyrometers at what were thought to be 'hot spots,' one pyrometer taking control for each direction of firing, or by the fitting of three or more pyrometers all in operation, the highest reading being selected automatically for control action. Air flow was normally set at a value in excess of that required for complete combustion, since additional oxygen was required for the chemistry of the steelmaking process.

Furnace pressure, normally set at about 0·1 in. w g and controlled by a damper in the waste-gas outlet, played an important part in furnace operation, since it could minimize leakage of cold air into the furnace or of hot-gas outwards. Inflow of cold air represented a considerable thermal load on the furnace and drastically modified combustion conditions. Leakage outwards gave heat losses, and flame 'sting' round the door, etc, may cause damage to furnace structure. The reversal sequence depended upon checker temperature, since the ingoing checker cooled as it warmed the com-

Robert Hare

Centenary of death of inventor of the oxy-hydrogen blowpipe

WITH SO MANY INDUSTRIES using the oxy-hydrogen flame for cutting and welding metals and fusing refractory bodies, the centenary of Robert Hare's death on May 15 is noteworthy. It is an occasion for noting how the invention of this young American brought such benefits and, in particular, gave rise to the American platinum industry when Joachim Bishop, who worked with Hare, founded the works of Bishop and Company of Pennsylvania. Since Robert Hare made his discovery when only 20 years old, it puts him on a par with those two other young Americans who made history in the field of technology: with Martin Hall, who, when 22, made his brilliant effort in producing aluminium by electrolytic means; and with Hamilton Castner who, at Oldbury, near Birmingham, England, created a sodium industry which gave cheap sodium cyanide and peroxide even after young Hall's process had banished overnight the well-established sodium-displacement method for aluminium at Oldbury.

Robert Hare came from a distinguished Philadelphia family on his mother's side. He joined the chemical society of that state when Joseph Priestley, discoverer of oxygen, was a member, this before lecturing to chemistry classes at the Medical School at the Pennsylvania University. If he had never introduced his famous oxy-hydrogen blowpipe, Hare would still be acclaimed a genius. For whereas he might have proved only an academic chemist of note with his 150 papers contributed to 'Silliman's Journal', with his professorship at Pennsylvania from 1818 to 1847, Hare possessed such constructive ability that he built an improved form of voltaic pile strangely called a 'deflagrator.' While Humphrey Davy had to use in his electrolytic preparation of the alkali metals an unwieldy pile incorporating troughs of acid, Hare's copper-zinc assembly permitted any number of voltaic couples to be brought into action. It was with this voltaic battery that Professor Silliman first fused and vaporized carbon in an electric arc, while with a later pattern iron and platinum were fused. Michael Faraday, in 1835, found that he was still trying to make improvements in voltaic batteries which Hare had already accomplished; hence he adopted Hare's invention forthwith.

In 1801 Hare described to the Philadelphia Chemical Society his 'hydrostatic blowpipe,' so-called since it used the products of decomposition of water. No other chemist had thought of burning together hydrogen and oxygen, even though Lavoisier had toyed with the idea of using oxygen for the production of intense heat. Hare's discovery was demonstrated to Priestley and was extended to a 'compound blowpipe' by Silliman, the invention winning Hare the Rumford Medal awarded by the American Academy. On Hare's centenary it must be emphasized that the young American had established priority over any claims made by Dr Edward Clarke of Cambridge, England. Clarke was a professor of mineralogy at Cambridge and in his 'gas blowpipe' had either overlooked or appropriated Hare's discovery and the work of Silliman. Although in the *Quarterly Review of the Royal Institution* he published an account of his experiments with 'Newman's blowpipe' (Newman was an instrument-maker who described his blowpipe 15 years after Hare's discovery), Clarke never publicly acknowledged the prior claim.

From his initial experiments Hare went on to improve his blowpipe and to demonstrate its potential uses on a large scale or beyond the laboratory walls. He incorporated a double platinum jet, with converging ducts forming extensions to two solid silver tubes conveying the two gases to a common passage just before the tip of the blowpipe. While Clarke used only one reservoir to hold the explosive mixture of gases and experienced such explosions as shattered copper vessels, Hare from the first saw that two gasholders were essential. He had made wrought iron containers 'capable of sustaining the pressure of the Fairmont waterworks.' Hare fused nearly two pounds weight of platinum, an intractable metal hitherto conglomerated only by the secret powder-metallurgy process of the English chemist, William Hyde Wollaston. He showed the fusing of more than 30 refractories not fused before; and with the use of refractory firebricks he invented the oxy-hydrogen furnace. Hare's jet was used to illuminate lighthouses and gave the world the 'Drummond light' and the 'calcium light.' Further, it was not only in America but in England and Europe that the fusing of platinum became the basis of a new platinum industry following the work of Henri Deville and his collaborator Henri Debray. These two pioneers in France had substituted lime blocks for Hare's refractory blocks, and with an improved oxy-hydrogen furnace had demonstrated to the firm of Johnson, Matthey & Co Ltd, of Hatton Garden, the new fusion and welding technique of platinum fabrication.

lowered into the converter. In that case, a major hazard was that the molten metal which was violently agitated might splash on to the instrument, and fume interference might still be a minor problem. An inferential method, also using a radiation pyrometer, measured the flame temperature by a modified Kohlbaum method. Experience had shown that flame temperature was directly related to bath temperature.

While those and other methods had been used on a limited scale, no standard technique comparable with, say, roof-temperature measurement in open-hearth practice had yet been evolved. The methods so far employed for end-point determination also left much to be desired. Ideally, the requirement was for an instrument which would continuously and almost instantaneously measure the phosphorus carbon, silicon and nitrogen contents of liquid metal without requiring the removal of a test sample, phosphorus content being by far the most important. Experimental methods at present used on a limited scale were inferential and were based on photo-electric measurements of one or more flame characteristics. Those included flame opacity and flame brightness measured in narrow colour bands. For each parameter the instrument recorded a maximum at a time t before the true end point; t was then calculated from a knowledge of rate of reaction, *i e* bath temperature, and pre-charge data on analysis, etc. It was claimed that those inferential methods allowed t, and therefore the end point, to be determined to a sufficient degree of accuracy.

The Bessemer process had to be regarded as a challenge to the instrument designer, since there were two clear requirements that could not be satisfied with existing techniques. It was unsatisfactory that one of the important steel processes showed such a gap in the field of industrial instrumentation.

Strip measurement and inspection

In the finishing processes, substantial progress had been made in certain directions. In rolling, for example, there was a need for information on produce dimensions, both at the outgoing end to satisfy customer requirements, and at intermediate stages to prevent overloading of the plant and to arrive at the correct final dimensions. In strip production the essential dimensions were width and thickness, and instruments had been installed to give that information. The problems associated with installation and performance requirements stemmed from the fact that sheet leaving a modern five- or six-stand tandem mill was at about 900—1,000°C and might be moving at speeds of up to 2,000 ft/min. Not only must the instrument be protected against heat and dirt, it must also be protected against severe mechanical damage, since there was a significant risk of the occurrence of a ' cobble ' in which the length of hot strip, weighing perhaps 5—10 tons, did not run smoothly down the run-out table but dug in and piled up upon itself, often to a height of 10 ft or more. It would be appreciated that this would take its toll of any instrument mounted over the run-out table unless adequate precautions were taken.

Thickness gauges so far employed fell into two classes. Radiation gauges were well known in many industries and had been employed in the steel industry. Sources employed were either x-ray tubes or γ-active isotopes; β-active sources had some application where the strip was sufficiently thin to allow adequate transmission. An alternative system, pioneered by B I S R A, made use of the mill itself as a measuring instrument. For a given gap setting S between the mill rolls, the exit gauge would be greater than S by an amount depending on the deformation of the mill rolls and the stretch of the mill housing under load. If that load was measured from the thrust on the roll screwdown, and the elastic constants of the mill were known, then the exit gauge could be computed.

Optical methods had been successfully employed for the measurement of strip width. Instruments had been developed by two British firms from a B I S R A prototype suitable for use on wide strip mill and measuring material up to 72 in. wide to an accuracy of $\pm\frac{1}{16}$ in. The meter consisted of two follower units, each of which acted as an edge follower unit. Those were set by a coarse control to the nominal width. Radiation from the strip edge was focused on an infra-red detector in each follower and a servo-operated shutter parallel to the edge of the strip cuts the image size to a fixed reference level. The movements of the shutter followed those of the strip edge and, by suitable summation of the movements of the two shutters, a value of strip width was obtained. Each unit also included a comparison beam of fixed size which was used to eliminate the variations in emitted radiation with changes of temperature. A number of defects might be present in rolled steel, arising chiefly from such defects in the parent ingot as shrinkage or gas cavities or solid inclusions. Lamination was a form of cavity in the finished material which seriously modified its mechanical properties. Ultrasonics had been successfully applied to the detection of lamination, particularly in thicker materials such as boiler and ship plate. Recent work by the firms specializing in ultrasonic equipment had eliminated, or at least reduced, the practical difficulties associated ten years ago with that type of inspection, and continuous examination of plate was now possible.

For thinner material, say 0·060 in. thick, he said,

bustion air, while the outgoing checker heated up. This sequence could operate automatically from checker temperature or on a time sequence, although manual control was usual.

Mr Smith said that the following variables were metered, and might form part of an automatic control loop in which the control action may be simple proportional or two- or three-term; roof temperature, ingoing checker temperature, outgoing checker temperature, fuel flow, fuel temperature, fuel pressure, air flow, air pressure, steam flow, steam pressure, waste-gas pressure, waste-gas temperature, waste-gas analysis and furnace pressure. It could thus be seen that pressures, temperatures and flow relating to the maintenance of predetermined plant conditions were adequately metered. But what of process variables ? The essential information was the chemical composition of the input, the charge and the output, and no direct and continuously reading instruments were available for that purpose. Information must be obtained by chemical or spectrographic analysis on discrete samples, removed from the process and analysed elsewhere. An essential additional source of information lay in the process operator's experience and skill. Fortunately, there was time available in normal practice for information to be obtained by those means, since a complete open hearth melt occupied some 10—12 h, and the 5 min or so occupied with a sample analysis did not delay the process significantly.

A similar situation, he pointed out, existed in the slab-reheating furnace whose function was to accept hot slabs at an unspecified temperature and discharge them at a specified temperature for further hot-rolling.

Mr Smith then discussed an oil-fired furnace in which the plant variables were completely instrumented but the slab temperature—the only process variable—was left completely alone. The furnace was divided into three combustion zones, each with its own burners and controls. The upper and lower tonnage zones were respectively above and below the conveyor carrying the slabs. At the outlet end a final soaking zone gave the slabs an opportunity to reach a uniform temperature throughout. Temperatures were measured by wall pyrometers in each zone and regulated the flow of preheated combustion air. Fuel was ratioed to air flow and atomized steam was regulated by a valve linked mechanically to the fuel valve. The air reheat was also regulated by a separate control system operating on a cold air dilution system. Waste gas from all three zones discharged to a common recuperator which preheated the incoming air. Furnace pressure was again controlled by one of two dampers in the discharge of the waste gases, part of which might be used in a waste-heat boiler plant.

Difficulties of Bessemer instrumentation

Those two items of plant might have given the impression that all steelworks plant could, with existing techniques, have most of their instrument requirements satisfied. Consideration of the Bessemer converter might give an exactly opposite impression. The Bessemer steelmaking process was widely used on the Continent and was of increasing importance and interest to the British industry. The converter was an ovoid vessel containing some 20—30 tons of metal per charge. Liquid metal direct from the blast furnace was poured into the converter and a high-pressure air blast was blown through tuyères in the bottom of the vessel. The oxidation of silicon carbon and phosphorus was an exothermic reaction and no additional heat—and therefore fuel—was fed into the plant. On straight air blowing, refining time was about 15 min, but latest pneumatic steelmaking techniques, employing an oxygen/steam blast, cut that time to about 8 min. Until recently, the only instruments to be seen on a converter stage would be a clock and an air-blast pressure indicator. With those simple aids and long experience, a blower was able to produce steel reasonably close to the desired analysis, his judgment being based on observation of the converter flame and on the general appearance of the melt. Recent work, especially in France and Germany, had had for its aim the removal of that element of chance in the process. The important variables were bath temperature, which determined the speed at which the reactions took place, and end-point determination. The end point was the point at which the phosphorus content was reduced to the desired minimum value. Over-blowing resulted in significant iron loss due to oxidation, while under-blowing left unwanted phosphorus in the metal. The margin between over- and under-blowing might be as little as 5 sec. Bath temperature was also important in relation to nitrogen pick-up, and to subsequent casting requirements.

It might be thought that continuous measurement of bath temperature would be relatively easy, but it had in fact presented considerable difficulties. Thermocouple pyrometers suffered from the disadvantages of fairly rapid contamination and low mechanical strength. Photocell pyrometers of both total and partial radiation types had been employed with some success but had brought their own problems. If the pyrometer was mounted above the converter and sighted through its nose on to the bath, the flame and fume emission tended to obscure the line of sight. Alternatively, the pyrometer might be housed in a water-cooled jacket and

paid in the plant if the performance of the instrument was 10—20% below specification. Gross instrument failures were usually self-evident and did not mislead the plant operator for any appreciable time, although if associated with automatic control systems they may have time to cause considerable damage to the plant or give rise to production losses. The detection of minor changes in, say, calibration was more difficult and such errors undermined the confidence of the plant operator in his instruments. A ' built-in ' standardization or checking facility, he said, was a valuable—one might almost say an essential—feature of a good instrument.

Future of steelworks instrumentation

In conclusion, ' at the risk of committing professional suicide,' he hazarded some forecasts of future needs and trends. Many instruments were installed at the moment which, although eminently satisfactory as instruments, were not the ideal instrument for the purpose. In general, standards of installation were good, since manufacturer and user had learnt, often by painful experience, how to protect instruments against steelworks environments. It was the instrument function and type of display which was often not correct for its purpose. A circular chart liquid flow indicator recorder was often installed, but investigation may show that the chart record was laboriously integrated by hand, and the real information required in the cost office was the total flow per day or per shift, and that the indication function was not used at all. Also one may have a recorder-indicator-controller complete with three-term control, when the essential requirement was for an indicator plus on-off control.

He thought that future emphasis must be on deciding precisely the function that the instrument was expected to perform, which for convenience might be classified under four headings: (1) Limit or alarm indication; (2) normal indication or the normal operational range of pointers moving up and down the scales; (3) recording, which may be divided into two categories—the permanent record, and the temporary or self-cancelling recorder, which recorded the information available on, say, the last shift basis or last half-hour basis; and (4) controlling, the control function of instruments. Furthermore, the instrument may be required to respond to the variable itself, its time derivative, its time integral or any combination of them. Selection and, if necessary, design of the right sort of instrument would become increasingly important.

Miniaturization, as an end in itself, did not appear to be warranted. There were rarely any restrictions on instrument weight (within reasonable limits) and size, and miniaturization could only be justified in the steel industry on grounds which were perhaps secondary considerations in other industries, such as comparative cost and ease of protection against industrial hazards. In the case of electronic equipment, he said, miniaturization often increased the difficulties of dissipating surplus heat, which was already a problem in the steel industry. As evidence of a contrary trend the use of 22-in. indicating instruments visible from a distance was widespread.

Increased emphasis, he continued, must be given to the reliability of industrial instruments. Mention had been made of maintenance difficulties in the steel industry, but these would be materially eased if the average industrial instrument had a reliability comparable to that of a good watch, which would run from two to five years with literally no maintenance whatsoever. It may be that such instruments could be produced now, but they would be expensive, and he pointed out that users would be unwilling to purchase such equipment if it was likely to be technically obsolete in a few years. This, he added, was surely a challenge to the instrument industry to give either long-term reliability with little maintenance at a reasonable cost, or low cost replacement with shorter-term reliability.

Recent advances in the technology of data logging and handling would have many applications in steel production. At present, thousands of documents circulated in the average steelworks, connecting long-term bulk orders with day-by-day production and with weekly programme schedules. It was possible to envisage a central record office housing an appropriate digital computer, receiving programme data from the sales office and production from all parts of the works, which would then issue future production schedules. Another possibility was the use of wire or tape to record process information in phase with the product from a continuous process such as a tinning line, if removal or correction of off-specification portions of material were required at a later stage, or if the customer required a foot-by-foot specification of a 5-ton coil of strip.

Mr Smith said that it had not been possible to do more than highlight a few of the areas in which instrument technology and the art of steelmaking overlapped. With the experience and example of the last two decades as a guide it was certain that the two would overlap considerably more in the future, and the instrument industry could play its part in helping the steel industry to produce more steel, better steel and cheaper steel.

Discussion

The chairman said that Mr Smith had, apart from showing the necessity of instruments in the steel industry, issued a challenge to the instrument

ultrasonic methods had technical limitations. Furthermore, the inspection must be carried out at high speed, since the product may be moving at 1,000 ft/min. A technique had been devised by B I S R A for these applications, and was based on the flow pattern of an electric current flowing in the material. The current flowed between opposite faces of the material and, if lamination was present, it was forced to flow round it. This modified the electrical potential existing at the surface of the material adjacent to the current injection points, giving rise to a measurable voltage. The two current and two voltage probes were in the form of a roller castor unit which traversed across the sheet. The search pattern traced out on moving material was approximately sinusoidal. Since lamination by its very nature was a defect extended in the direction of rolling, a pattern of this type gave a high probability of intercepting and detecting a lamination longer than about half a wavelength of the sinusoidal scanning pattern.

Tinplate production was a well-developed process which, however, did not so far employ many continuous quality-control inspection devices, yet the efficiency of tin as a protective film depended upon the quality of the base steel, the thickness and uniformity of the tin coating and its freedom from surface blemishes. Surface inspection was normally carried out visually by an inspector who assessed surface reflectivity. While it was feasible to produce an optical system which would carry out a point-by-point surface scan, the automatic interpretation of data obtained by such means was not easy, but it would undoubtedly come in the future, since the potential rewards in consistency of operation, freedom from fatigue and higher speed of operation would be of value in meeting more stringent customer specifications.

Methods of measurement of coating thickness had already been developed for the inspection of stationary samples and were of value in spot checks. One such instrument relied on eddy current phenomena. A small search coil formed one arm of a balanced a c bridge. When the coil was put against the tinplate sample, eddy current loading of the coil led to a bridge unbalance, which could be interpreted in terms of the conductivity of the sample. If the bridge frequency was high enough, eddy current penetration was restricted to the surface coating of tin, and so could give a measure of coating thickness. For the inspection of moving material the back-scattering of x-rays had been tried, both in the U K and the U S A, but further experience of the method was still required.

Inspection of the ingoing steel strip, he continued, had been referred to while discussing the detection of lamination. Another defect detected at that stage was pinholing. Pinholes, he said, were small holes through the strip, and photo-electric pinhole detectors were commonly installed. They relied on a straightforward obscuration technique with a strip lamp across and above the steel with a corresponding strip photo-cell below.

Maintenance problems

Mr Smith said that these examples had been given to illustrate the type of instrument and control problems facing the iron and steel industry, and to show the considerable advances made in certain directions, notably in relation to the correct use of fuel. It should be remembered, however, that the industry was an old established craft industry, and the basic items of plant had changed little in their essentials in the last 50 years. In most cases, instrumentation had been added to improve the efficiency of an already operating plant. In its train it had brought a new range of problems centred on maintenance. One medium-sized works claimed to have 4,800 instruments of a wide variety of types ranging from a simple Bourdon pressure gauge to a quantometer. To give good, reliable service they must be maintained, for which purpose an adequate maintenance staff was essential. This posed the first problem, since the industry found the greatest difficulty in obtaining enough of the right kind of staff for their work. There were several reasons for this, some of which were purely domestic issues, and they varied from works to works. The resultant staff shortage was common to most works, however, and few instrument maintenance departments could claim to have enough adequately skilled men. The increasing extent of instrumentation in the industry was constantly bringing new techniques into everyday use, and in many cases the existing skilled man was unable to broaden his skill to keep pace. This situation, he added, may be aggravated by inadequate technical literature and assistance from the instrument supplier, since the service given in that direction by the instrument industry varied from excellent to very poor indeed. Thirdly, the increased complexity of some modern equipments taxed the resources of local maintenance staff and facilities, although they may be perfectly capable of handling simpler equipments based on the same principles.

Steelworks instruments maintenance seemed to be organized on a number of different lines. These ranged from the well-organized preventive maintenance schedule, through the curative maintenance system to the other extreme of 'run-it-till-it-breaks-then-ignore-it school.' While it was patently clear that the first system was much to be preferred on purely technical grounds, it may not necessarily offer the best economic return. The optimum system may well depend upon the penalty to be

Concentrated wear of turning tools

Experiments on some aspects

V. SOLAJA, Dipl Ing, A M I Mech E, and
D. R. CLIFFE, B Met, A I M, A M Inst F

Experiments on some aspects of concentrated wear of carbide-tipped tools have been carried out, and the main conclusions so far reached reviewed by the authors. The work was done at the Wolverhampton and Staffordshire College of Technology, Wolverhampton, where Mr. Cliffe is lecturer in metallurgy. Mr. Solaja is at present with the Faculty of Mechanical Engineering, University of Belgrade

CONCENTRATED WEAR in the form of grooves which develop on the clearance face of a carbide-tipped tool when steel is turned has been examined in earlier work.[1, 2, 3, 4] A set of possible causes of this phenomenon was proposed recently,[5] and attention drawn to some technological consequences.[6]

The critical regions for concentrated wear are the intersections of (i) the leading edge with the surface generated in the previous traverse and (ii) the trailing edge with the surface generated in the previous revolution. At a distance from the first groove equal to the tool-feed, the crests of feed-marks may reach the trailing edge, thus initiating a second groove. Eventually, a number of grooves may develop in like manner (fig 8).

Experiments on some aspects of concentrated wear have been carried out at the Wolverhampton and Staffordshire College of Technology, Wolverhampton, and the main conclusions reached so far are reviewed in four sections.

(1) Hovenkamp and van Emden[2] have suggested that a crack may develop when the tool engages the workpiece, thus being responsible for localized wear.

In figs 1 and 2 both faces of a carbide-tipped tool are shown after fine-finish turning mild steel for only 3 sec. It appears that the localized wear started at the edge and, while increasing in length to approximately 0·001 in., the groove moved in the direction of feed. The ' groove ' on the rake face may be deceptive at this stage of cutting because, after applying 10% HCl, most of the marks were removed. This suggests that they consisted of the workpiece-material adhering to the surface. The clearance face remained virtually unchanged.

Therefore, it appears that the origin of the concentrated wear under the trailing edge is not attributable to a local minute breakdown of the cutting edge.

(2) Attempts have been made to connect groove-formation with the work-hardening of the machined surface,[2] and to explain in this manner localized wear under both leading and trailing edges.

In our experiments mild steel was faced with a carbide-tipped tool, the straight cutting-edge being parallel to the axis of rotation. The way in which the concentrated wear is affected by the method of preparation of the testpiece is reviewed in Table I.

In fig 3 is shown a microphotograph of the outer faced surface within the localized wear from experiment (*c*). The ferrite (light)/pearlite (dark) structure is considerably distorted in the surface

TABLE I *Wear magnitudes in cutting 0·40% carbon steel with Mitia TE carbide-tipped tools:* $\alpha = 0$ *deg,* $\gamma = 8$ *deg,* $f = 0{\cdot}0025$ *in/rev,* $v = 250$ *ft/min,* $L = 200$ *ft*

Preparation of the face of the testpiece	B (inches)	B_1 (inches)	Remarks
(*a*) Fine machined and sanded	0·00030	0·00045	
(*b*) Rough machined	0·00050	0·00110	
(*c*) Knurled to a depth of 0·010 in	0·00040	0·00230	Width of groove slightly larger than the depth of knurling
(*d*) Rough burnished with a high-carbon shank	0·00045	0·00320	Local breakdown of the edge

makers, which was a good thing for the steel industry and instrument manufacturers, both of whom were trying to serve industry generally. He thought that in the steel industry the aim should be to get the end product right, and he suggested that one of the first things in achieving this was the elimination of variables at source; it was, he said, too late when an end point detector showed that the produce was wrong. There should be control of the variables at source so that the end product was as near right as possible.

Dealing with Mr Smith's reference to indicating and recording, he said he had always felt that if a thing was worth indicating it was worth recording, because the recorder had the great advantage that it showed a trend of where something was going and the rate at which it was going, whereas an indicator, even if logged spasmodically with the greatest accuracy, could miss the high point. With recording, he pointed out, in industry one was interested in deviation away from perfection, and a recorder was one of the finest things for showing the deviation.

In reply, Mr Smith agreed that it was better to correct deviations early on in a process rather than detect it at the end, but said that the first requirement always was to have a detecting instrument to show how wrong the process was, so that the process and chemical engineers would accept that something would have to be done about it; until they were given some evidence that the end product was not up to specification they were as a rule only too happy to carry on as they had been.

He disagreed that if information was worth indicating it was also worth recording. In steelworks offices, particularly of fuel engineers, he had seen pegged up masses of paper charts, circular and linear, which had been steadily accumulated, and he was certain that in many cases they were never looked at two or three weeks after being removed from the instrument. He thought there was a very strong need for a type of recording instrument which would reproduce information on a shift, or possibly weekly basis, which did not require a paper record to be removed at the end of the operation, but which cancelled itself.

There were three ways in which data produced by a measuring instrument could be used. The first was direct use of the information when the operator himself looked at the instrument and used the information gained to regulate the processes; the second was what might be unkindly called the 'big brother act' whereby managers could use what was essentially short-term storage of information, usually on a shift basis, in order to examine what work had been done. Thirdly, there was what might be described as post-mortem analysis information which could be used for explaining why a particular piece of equipment had gone wrong or for the correlation of data for the benefit of future operators of the process and generally enhancing the information that already existed about it. In general, if a process was ticking along quite happily in the light of commonly accepted practice the information collected by recording instruments was substantially valueless.

Another speaker said that, as a person in the instruments industry associated for some years with the design and development of service equipment, he was appalled to think that an instrument could not be produced which would stand up to conditions in steel works.

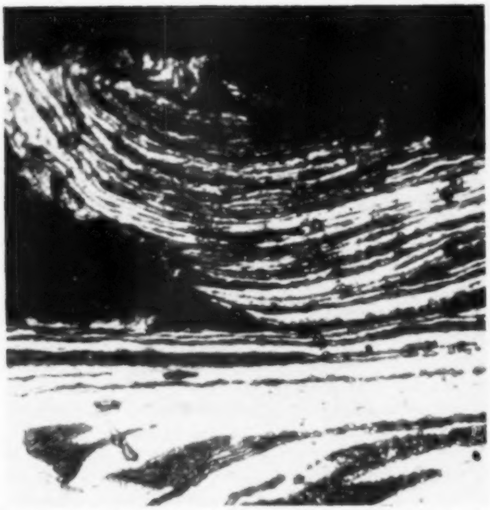
Mr Smith said he had intended no criticism of the suitability of instruments for that particular environment but rather the way in which they reacted to that environment when they were called upon to run non-stop for really long periods, not just for seven days. What was needed was an instrument which would run for as long as two years in a sealed case which nobody would open in any circumstances. That sort of performance was obtainable from a wrist watch of quite ordinary quality.

In reply to further comments about the desirability of storing information, he said the problem of doing that in any useful form was a matter which affected any industry. Generally speaking, he felt that there had not been a rational appreciation in his industry of the precise function for which they wanted to store the information. The only generalization he was prepared to make was that in 99 cases out of 100 the pen record on paper chart was far and away the most inefficient way of doing it in the light of modern developments in data recording.

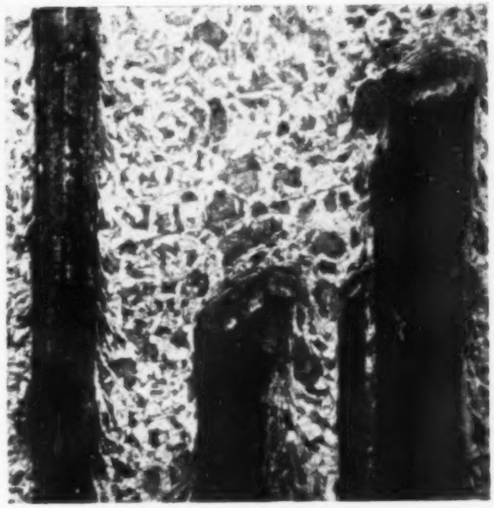
A final speaker said that one of the difficulties about developing long life for equipment was that of convincing the customer that the initial capital cost of such equipment was really negligible. It was also true that many of the tests and specifications for service equipment were intended to discover the minimum life under which failure could not occur rather than the question of extremely long life under service conditions.

Vacuum and induction furnaces

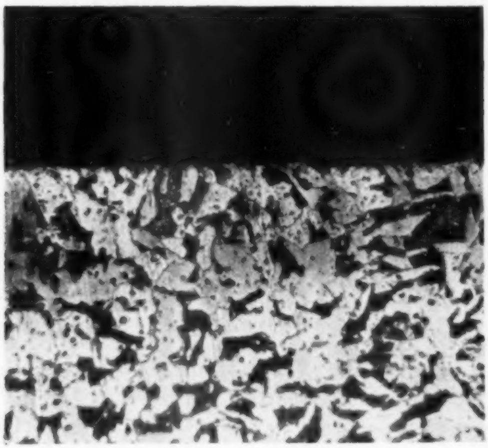
Less than twelve months after receiving Treasury approval to the agreement under which Wild-Barfield Electric Furnaces Ltd are manufacturing vacuum-arc, induction and resistance furnaces and vacuum analysers to the designs of National Research Corporation, Massachusetts, U S A, the Vacuum Division reports very satisfactory progress. There are in hand a considerable number of vacuum furnaces, including the largest induction-heated equipment in the country and other units for melting and casting beryllium and uranium. In addition numerous orders are in hand covering vacuum gas analysis equipment.



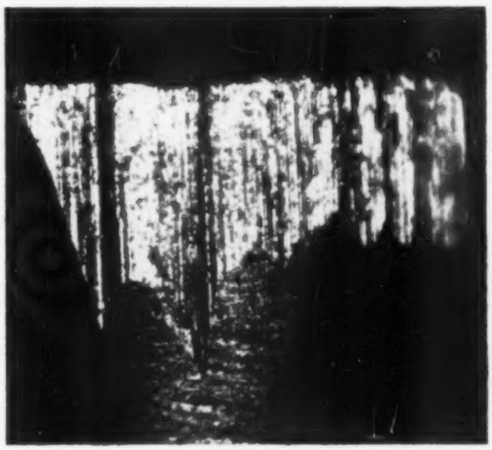
5 *Detail of the deposited particle of the built-up edge from fig 4 under higher magnification (×1,000), direction of cutting from left to right*



6 *Shallow-polished and etched machined surface from the experiment shown in fig 4. Direction of cutting upwards, magnification ×200*



7 *Section perpendicular to the surface generated in fine-finish turning 0·40% carbon steel with the same tool as in fig 1, cutting speed v = 850 ft/min. Start of cutting; direction of cutting from right to left, magnification ×200*



8 *Clearance face of a worn carbide-tipped tool at the end of experiment shown in figs 7 and 9, with three grooves formed under the trailing edge. Direction of cutting from left to right, magnification ×180*

layer, and this is continued in the deposited projections of built-up edge. These projections appear to have a higher percentage of pearlite than in the neighbouring material.

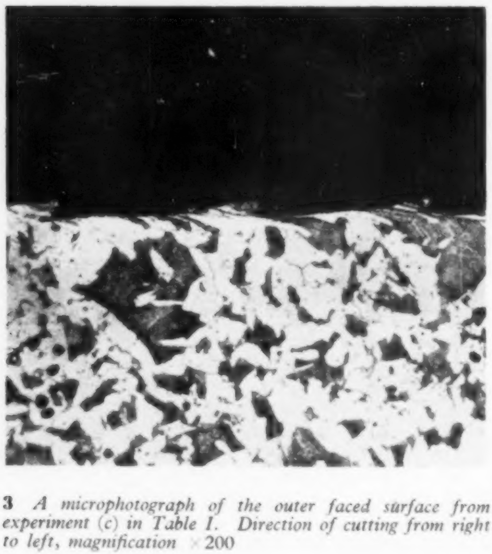
The depth of the deformed layer and the frequency and size of the deposited particles are less outside the boundary region of localized wear, which might be connected with the mechanism of escape of the built-up edge *via* the groove as suggested recently.[3]

Consequently, the following conclusions may be drawn: (i) The condition of the surface layer affects the intensity of localized wear under the trailing edge, but it does not appear that work-hardening is the sole cause of groove-formation.

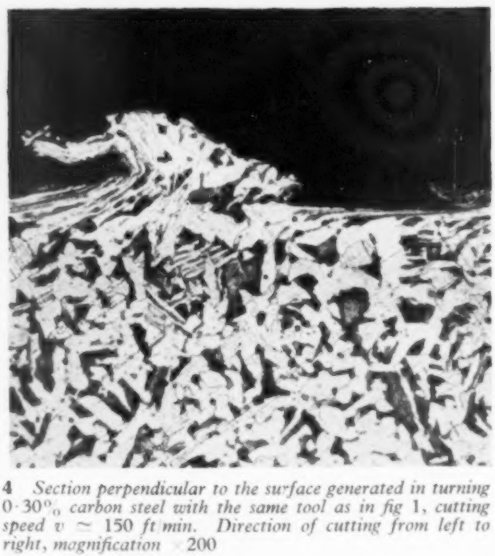
(ii) Deformation of the surface layer is more

1 *Clearance face of a Mitia TE carbide-tipped tool (rake angle $\alpha = 0$ deg, clearance angle $\gamma = 8$ deg, tool-nose radius $r = 0{\cdot}020$ in) after cutting $0{\cdot}30\%$ carbon steel. Length of cutting $L \simeq 50$ ft (cutting speed $v = 950$ ft/min, depth of cut $t = 0{\cdot}005$ in, feed $f = 0{\cdot}004$ in/rev) with the groove under the trailing edge. Cutting from left to right, magnification* $\times 1{,}100$

2 *Rake face of the tool from fig* 1. *Cutting from right to left, magnification* $\times 600$



3 *A microphotograph of the outer faced surface from experiment (c) in Table I. Direction of cutting from right to left, magnification* $\times 200$



4 *Section perpendicular to the surface generated in turning $0{\cdot}30\%$ carbon steel with the same tool as in fig* 1, *cutting speed $v \simeq 150$ ft/min. Direction of cutting from left to right, magnification* $\times 200$

All photomicrographs taken with a Vickers projection microscope

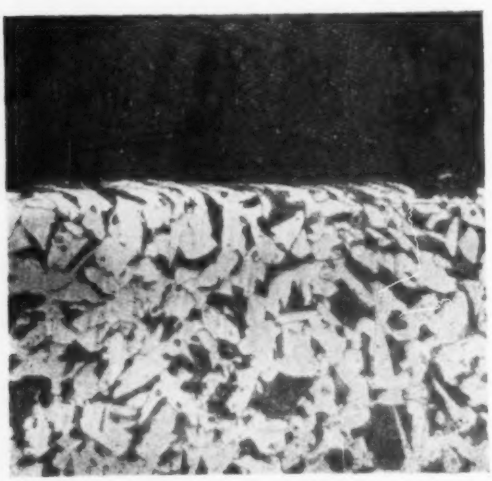
severe near the contact with the localized wear than at the rest of the interface. This indirectly confirms the assumed relationship of the magnitude of tool-wear and of residual stresses of the machined surface.[7]

(iii) Concentration of the particles of the built-up edge at the outer end of the machined surface appears to confirm the findings by Albrecht[4]. Similarly in the case of knurled surface (*c*), this might be connected with the localized wear caused by fatigue.

(3) It is well known that, in turning mild steel, a low cutting speed is accompanied by a rough, torn surface.

Fig 4 shows a section obtained from such an experiment. The surface layer was very distorted, and the particular area shows two types of irregularities: (i) large distorted protrusions, retaining the relative ferrite/pearlite percentages, and apparently continuous with the neighbouring parent metal (on the left), and (ii) smaller particles, similar to those in fig 3, highly distorted and embedded into the surface (on the right). In fig 5, at a × 1,000 magnification, it can be seen that the matrix of this particle is severely deformed, the percentage of pearlite has increased, and it no longer appears to be continuous with the neighbouring material. A shallow-polished machined surface from the same experiment is shown in fig 6. Along the edges of the machining grooves, ferrite/pearlite flow is present, and two deposits with circumferential flow may be noticed.

Both sections indicate that concentrated wear by fatigue may occur, being due to a periodic loading



9 *Section perpendicular to the surface generated in the experiment shown in figs 7 and 8. End of cutting; direction of cutting from right to left, magnification ×200*

of the cutting edge along the critical boundary regions of the clearance face. It also appears that the ' cracks ' in surface layers reported by Chisholm[8] could be partly attributed to the particles of the built-up edge embedded in the surface already machined.

(4) It is usually assumed that for cutting speeds above 500 ft/min, using a sharp tool, no detectable depth of deformation of surface layer is present.

In further experiments the influence of tool-wear on the deformation of the surface layer has been investigated in fine-finish turning mild steel with carbide-tipped tools. Fig 7 shows the section perpendicular to the surface generated at the very start of the experiment (*i e* with a virtually sharp tool). Practically no deformation of the ferrite/pearlite can be noticed. However, after a length of cutting of $L = 8,500$ ft, considerable concentrated wear on the clearance face was noted (see fig 8). The depth of the deformed layer was nearly 0·0008 in., as apparent from the microphotograph (fig 9).

These results show that, with a high cutting speed also, the residual stresses in the surface layers increase with tool-wear, the depth of the deformed layer reaching eventually an appreciable value.

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British steel for Brussels exhibition

In anticipation of the heavy vehicular traffic at the exhibition, the Belgian Government have had guard rails erected at certain of the pedestrian crossings. The contract was awarded to a British firm, Rollo-Hardy & Co, Blaenrhondda, Glamorgan, to supply rails from polished austenitic stainless steel. More than 50,000 ft of rail was provided for local contractual fabrication, in two sizes of rectangular welded stainless steel tubes, the value of the contract being approximately £25,000. Rollo-Hardy & Co is a subsidiary of the Compoflex Group of Companies.

British films at Brussels exhibition

Three documentary films, made for Firth-Vickers Stainless Steels Ltd, by the Brown Firth Research Laboratories, have been selected by the British Iron and Steel Federation for showing at the Brussels Universal and International Exhibition.

The films selected are: ' Stainless steels in power production ', ' The manipulation of corrosion and heat-resisting steels ' and ' Where " Staybrite " steels are made.'

The forging of heat-resisting metals

The late A. H. WAINE, Assoc I Mech E, F I M, and J. R. RAIT, D Sc, Ph D

An attempt is made to describe some important aspects of general interest in connection with the forging of the wide range of heat-resisting metals used in the engineering field. After briefly indicating the scope of heat-resisting metals, various forging aspects and metallurgical factors are discussed, followed by some new developments and processes being introduced in order to solve problems associated with the forging of materials which have been specially developed to offer strength at elevated temperatures. The following article has been slightly amended from the paper presented at the Conference on Technology of Engineering Manufacture, arranged by the Institution of Mechanical Engineers, London, March 25-27, 1958. Mr Waine was director, Hadfields Ltd, and managing director, Hadfields Forgings Ltd, and Dr Rait is joint managing director, Briton Ferry Steel Co Ltd

HEAT-RESISTING METALS may be generally defined as those metals which offer resistance to oxidation and scaling, coupled with adequate strength at elevated temperatures. The term 'elevated temperature' is purely arbitrary and in this paper temperatures of about 300°C and above have been considered. In the case of many heat-resisting forgings their resistance under stress to slow plastic deformation at elevated temperature, that is, their resistance to creep, is the governing factor in the selection of material although other characteristics such as thermal expansion, thermal conductivity, thermal shock resistance, machinability, resistance to abrasion and resistance to specific types of atmospheric contamination, etc., may all be of importance. A valuable historical survey of the development of such creep-resisting materials up to about 1950 has been given by Allen.[1] Since that date one of the most notable achievements has undoubtedly been the commercial production and forming of the titanium-base alloys.

Although heat-resisting forgings are produced essentially by conventional methods, their application in vitally important and highly stressed components poses many new problems for the metallurgist and forgemaster. Many heat-resisting components, such as gas-turbine engine blades and discs, operate under conditions in which the service stresses approach the strength of the material and, furthermore, in order to reduce the weight of the components to an absolute minimum, extremely thin sections are frequently required. In addition, many heat-resisting materials are difficult to machine and are expensive, hence the need for forgings produced to close dimensional tolerances in order to reduce expensive machining operations and wastage of valuable metals. Also a very high standard of cleanness in the material, close metallurgical control at all stages of production and stringent inspection tests are necessary. As an example the increasing use of ultrasonic examination[2] as a means of detecting possible internal defects in large forgings may be cited. These requirements impose a particularly onerous responsibility upon the forgemaster who must plan his forging procedure in full co-operation with the metallurgist in order to obtain the optimum properties in the finished component. For these reasons and because of their greater uniformity, forgings are often preferred to castings and, as an example of this, may be cited the reluctance on the part of engine designers in Britain to accept the use of cast moving blades in the aircraft gas-turbine. It should not be concluded from this, however, that lack of reproducibility is an inherent characteristic of castings. With adequate technical knowledge and control of the casting process many of the objections to castings are capable of being overcome.

Forging aspects

It is not proposed to catalogue the numerous types of forging plant which are available but merely to draw attention to some factors which are of particular interest when considering the forging of heat-resisting materials.

For the production of large forgings such as

chemical pressure vessels and turbine rotors, there is no alternative to the use of the forging press.[3] With the growing demand for larger forgings and the development of stiffer heat-resisting materials, very powerful and quick-acting presses are becoming more and more necessary.

There has been a marked trend in recent years toward the use of rail-type manipulators for use with forging presses, although for smaller plants mobile manipulators up to a capacity of about 7-ton ingots are also being employed. Whilst the presses themselves have not basically undergone any major changes in recent years, most large modern presses are equipped with servo control which largely eliminates fatigue on the part of the press driver. In some installations transverse as well as longitudinal table-shift arrangements and devices such as hydraulically operated 'knife'-handling equipment are employed. The aim of many of these improvements is to achieve more work per heat, thereby reducing the number of reheatings necessary. The control of press, turning gear, and cranes may be effected from a joint platform where the operators sit together so as to be able to work more easily as a team. Radio contact between the control stand near the press and handling cranes in other parts of the shop has been provided in some cases to promote easy co-ordination. So far as the performance of the presses themselves is concerned, considerable research and development has been carried out in the U K in the last year or so, and a very much better understanding now exists of the performance actually obtained from the various alternative forms of drive that are being utilized. The choice of drive is now virtually confined to accumulators or direct drive, the latter being effected by water pumps or, more particularly in the case of several small presses, by oil pumps. Oil, however, has clear disadvantages as a work medium in a forge in that it is inflammable, it tends to pick up dust particles and its leakage in a forge is unpleasant and can be dangerous. The direct drive arrangement, as such, results in some power savings and the actual penetration performance achieved with the system in good condition can be quite satisfactory; nevertheless, accumulator drive for forging presses is finding universal acceptance, being used in increasing measure in installations in all countries.[4]

The demand for larger high-quality forgings has seen a trend in some quarters toward the upsetting of forging ingots.[5] Upsetting is carried out for two reasons. First, it is considered that the upsetting and subsequent cogging back of an ingot helps to close up central porosity and, secondly, by upsetting to increase the cross-section of an ingot it is generally possible to produce a forging from a smaller ingot than would otherwise be the case. This it is believed results in a better-quality forging since segregation and porosity are usually less severe the smaller the ingot. Recent experimental work carried out by the British Iron and Steel Research Association[6] suggests that in order to obtain the benefits desired from upsetting, a fairly high upset ratio may be required and this again emphasizes the need for presses of adequate power if the highest-quality forgings are to be produced. Table I lists as far as is known the principal forging presses of the world, of about 5,000 tons and over, exclusive of those used for special work such as armour bending, railway wheels and tyres, and non-ferrous die forging. It will be seen that Great

TABLE I *List of the world's heavy forging presses (approximately 5,000 tons and over)*

Country	Press tonnage	Date built
Great Britain	6,000	1911
	6,000	1934
	7,000	1913
United States of America	6,000	1945
	6,500	1920
	6,500	1944
	7,000	1944
	7,500	1904
	7,500	1940
	12,000	1900
	14,000	1893
	14,000	1919
	14,000	1944
	14,000	1944
	14,000	1945
Canada	7,000	1954
Russia	6,000	1914
	6,000	1934
	10,000	1934
	10,000	1934
	12,000	1939
	15,000	1935
Germany	5,000*	1908
	5,000*	1941
	5,100*	—
	5,100*	—
	6,000	—
	15,000*	1928
	15,000*	1932
France	6,000	1921
	6,000	1906
	6,000	—
	6,000	1914
Italy	4,500	1910
	5,000	1938
	8,000	1938
	8,000	1934
Japan	5,000	1938
	5,000	1938
	6,000	1916
	10,000	1937
	12,000	1938
	15,000	1935
Czechoslovakia ..	4,500	1908
	5,000	—
	6,000	1933
Holland	6,000	1957

* Dismantled after the 1939-45 war

Britain has no large presses in the 10,000—15,000-ton range. However, a new free forging press of 15,000 tons capacity is projected for the Sheffield district, that is, more than double the power of the largest free forging presses at present available in Great Britain.

The question of the design of press tools in so far as they affect the quality of the finished forging is not always fully appreciated and again much valuable work has been carried out by B I S R A.[7] As an example of the hazards attending even apparently simple forging operations, mention may be made of the difference between the forging of square and round blooms. Whereas the former is a comparatively safe operation, the latter can produce severe tensile stresses at the centre of the section, leading in certain cases to actual rupture. Such stresses can be reduced by attention to tool design, such as the use of swages or V-blocks of the correct size instead of flat tools.[8]

For the forging of smaller ingots and components, forging hammers are available, the deformation in this case being produced by an impact blow, as opposed to the relatively slow squeezing action of a press. In such forging hammers the tup may fall under gravity or it may be accelerated by means of steam or compressed air. It may be pointed out here that the conventional practice of rating hammers according to the weight of the moving tup is not entirely satisfactory, as consideration must also be given to the additional weight of any top tools or dies, the accelerating effect of steam or air pressure if used to assist gravity in driving the tup and the distance through which the tup moves. A more realistic approach is to consider the kinetic energy of the tup at impact. In order to overcome difficulties associated with the design of foundations for large drop hammers the counter-blow hammer was developed in Germany in the early 1930s and may receive more attention in the future.[9] In this type of hammer two counteracting rams are employed, the lower ram replacing the anvil of the conventional hammer. The moving bottom die does, of course, preclude the use of this hammer for work requiring hand manipulation.

The decision as to whether a given component is forged under a press or a hammer is often dictated by necessity rather than choice. Little published information is available on the relative merits of hammer and press forging, either as regards their effect on the mechanical properties of the finished forging or their suitability for materials which are inherently difficult to forge. The relatively slow squeezing action of a press would be expected to produce less severe stresses than the impact blow of a hammer. However, with the relatively slow action of a press, localized cooling can occur at the point of contact of tool and workpiece with the subsequent formation of forging cracks. A quick-acting press with its reduced time of contact has a distinct advantage in this respect.

The production of profiled forgings of large surface area such as turbine discs can be carried out in dies in either forging presses or hammers of the drop or counter-blow type. The choice, again, appears to be dictated by the equipment available. In the case of flat discs which are subsequently profile-machined the power required may be considerably reduced by step forging, using a relatively narrow top tool. The method of producing a particular component is, in many cases, determined by the economics of the process including the quantities involved. Although the development of very large die forging presses for repetition forging has been actively pursued in the light-alloy field for the production, for example, of aircraft wing spars, little work has been carried out on the forging of heat-resisting steels by this method. However, compressor discs of 19 in. dia 12% chromium steel have been produced by closed-die forging under a large press.

For the mass production of small closed-die forgings such as Nimonic, titanium, or stainless-steel aircraft compressor and turbine blades there is a tendency toward the use of vertical mechanical presses in preference to hammers (*Automobile Engineer*, 1950). Apart from any technical advantages, it is easier to train operatives to handle presses than hammers and the comparative absence of noise and vibration makes for more pleasant working conditions. When coupled with ancillary equipment such as roll-forging machines the versatility of the forging press is very considerably improved.

As an illustration of the use of several alternative forging methods for a given component, the production of high-temperature diesel-engine exhaust valves may be cited. These may be made either by hand forging, a process particularly suitable for small batches of special design, by electric upsetting, or by the extrusion process. The forge extrusion process produces a superior grain flow and there is no doubt that many developments of the extrusion technique will be seen in the future for small precision forgings.

Heating for forging

Accurate control over heating for forging is essential for the production of high-quality work. In the main, oil-fired or gas-fired furnaces are used but there has been, in recent years, where the method is economically justified, a considerable extension of electrical heating, using either resistance furnaces or electrical induction methods. Considerable strides have been made in the application of induction heating in shops which are

subsequently becked out under a forging hammer to produce rings having satisfactory mechanical properties. In this way it may be possible to produce larger ring forgings than would otherwise be obtainable from the maximum size of ingots at present available.

A great deal of interest has been aroused by the publication of the vacuum casting process more recently developed in Germany for the casting of large steel ingots.[12] It is claimed that by casting ingots under vacuum the hydrogen content of the steel is reduced to about a half of its initial value, together with some reductions in nitrogen and oxygen. There is also some volatilization of deleterious impurities such as zinc, copper, tin, and lead. The removal of hydrogen is of particular importance as, if not removed, it can produce hair-line cracks in ferritic alloy steels. Freedom from such defects is of the utmost importance in highly stressed components such as turbine rotor forgings,[13] even if it should be necessary to resort to expensive and time-consuming heat treatments. By producing steel ingots of low hydrogen content the diffusion treatment given to large forgings may be considerably reduced or even eliminated altogether.

A considerable amount of experimental work is being carried out on the process of vacuum-melting steel and heat-resisting alloys, and equipment is now available for melting and casting heats up to 1 ton in weight completely under vacuum or inert atmospheres. By vacuum melting it is hoped to obtain alloys free from harmful non-metallic inclusions and dissolved gases, with increased toughness and fatigue resistance, factors which are particularly important for components such as gas-turbine-engine discs and blades.

In view, however, of the difficulty and expense of producing large forging ingots by vacuum-melting techniques, attention is being directed toward the possibility of obtaining the required properties from vacuum-cast material, a process which has already been successfully adapted to the production of ingots up to 150 tons in weight, and some work along these lines is already being carried out.

An alternative method for the production of vacuum-melted ingots is that of consumable electrode-arc melting, a process which is now standard practice for titanium ingots up to at least 20 in. dia. The technique can be extended to produce larger ingots and it is applicable to materials other than titanium.[14] An interesting feature of the process is that only a relatively small portion of the ingot is molten at any one time and with properly controlled double-melting operation titanium alloy ingots can be made free from central segregation.

Certain very refractory metals such as tungsten, molybdenum, niobium and tantalum, all of which are being used or have potential value as heat-resisting materials, are shaped from sintered compacts. The compact can be hammered and pressed with conventional equipment and, if required for subsequent wire drawing, forged down to about $\frac{1}{8}$ in. dia bar in rotary swaging machines. Tungsten and molybdenum are heated in a reducing atmosphere at 1,200—1,500°C for forging but, because of their vogorous reaction with the atmosphere at temperatures above that required for softening, niobium and tantalum are forged cold.[15]

A further interesting development of the forging of sintered products is the manufacture of a sintered aluminium powder (S A P),[16] which is essentially an agglomerate of aluminium flakes with 11—15% aluminium oxide. After cold pressing to produce a compact of specific gravity about 2 and hot working at a temperature of 500—600°C it has useful strength/weight properties as compared with aluminium alloys and commercially pure titanium.

Mechanical properties

The influence of processing conditions upon the mechanical properties of forgings has been the subject of considerable study and many of the factors involved have been established. In the case of heat-resisting alloys, however, some additional considerations obtain, and these serve to make forging conditions still more important.

Many of the creep-resisting alloys in current use depend for their high-temperature properties upon an initial dispersion of metallic carbides and/or intermetallic compounds in a ferritic or austenitic matrix. Although the dispersion is ultimately achieved by heat treatment involving high-temperature solution and subsequent precipitation of secondary phases during tempering, the efficacy of this treatment is largely conditioned by the as-forged structure. In the ingot the condition of the carbides or intermetallic compounds is that of coarse-grained entities which generally surround the grain boundaries and it is essential that this network be adequately broken down during forging so that, in the final heat treatment, only small particles are required to be dissolved.

The presence of the grain boundary network referred to above results in a structure which is inherently brittle at high temperatures and, for this reason, the ingot must be very lightly worked during the early stages of forging. With the progressive breakdown of the intergranular material increasing amounts of deformation can be applied during the final forging operations.

It would appear from the foregoing considerations that where maximum creep resistance is desired the maximum possible forging reduction should be employed in order to achieve the optimum breakdown and subsequent solution of carbides and

mass-producing small components from material of uniform cross-section, but the method has not been satisfactorily developed for the reheating of partly formed forgings of non-uniform section.

Electrical heating has an advantage in that the furnace atmosphere can be readily controlled. As examples of the need for paying careful attention to the type of atmosphere, mention may be made of the deleterious effects of hydrogen contamination in titanium alloys (now overcome to a large extent by the manufacture of titanium sponge of low initial hydrogen content) and the serious embrittling effect of sulphurous atmospheres on nickel-base alloys such as the Nimonic series.

Whilst a material may be heat resistant in an operational sense it may none the less be readily overheated, or even ' burnt,' if due precautions are not observed during heating for forging, and hence the need for careful consideration of the type of furnace to be used. The term overheating normally embraces all structural coarsening, in excess of normal expectation, arising from excessive or prolonged heating during manufacture. Fracturing a sample of the steel, after hardening and tempering, is frequently adopted as a means for detecting overheating, which is then evidenced by an unusually coarse and faceted fracture.[10] The degree of reduction of the material after heating must also be taken into account, however, since a considerable structural refinement occurs during the course of hot working.

Mild forms of overheating may arise in the later stages of forming of a complicated forging, parts of which may unavoidably be reheated although they are not to receive any hot work. The properties of an overheated structure can sometimes be recovered by subjecting it to one or more cycles of heat treatment selected with a view to the refinement of the coarsened structure. The same cannot be said of a ' burnt ' material which, accepting common usage, has been heated to the point of incipient melting, thereby producing permanent damage along the grain boundaries which no practicable thermal treatment can repair.

The lower limit of the forging temperature range for heat-resisting materials is often as important as the upper limit, if cracking is to be avoided.

Metallurgical considerations

Many of the difficulties associated with the forging of heat-resisting metals are encountered at the initial stages during the breaking down of the cast structure of the ingot. As is well known, a conventionally cast ingot is not homogeneous. As cast under normal conditions the ingot generally consists of crystals arranged in three ways: a thin outer layer of small chill crystals, columnar crystals which are perpendicular, or nearly so, to the walls of the mould, and equiaxed crystals with random orientation in the interior. A structure of the type in which coarse columnar crystals have grown right to the centre of the ingot is undesirable and requires very careful working, particularly during the early stages of forging. Owing to shrinkage of the metal during cooling and solidification, internal voids or ' pipe ' may be formed along the axis of the ingot and, in addition, as solidification proceeds there is a tendency for impurities such as sulphur and phosphorus to segregate in the last portions of the ingot to freeze.

The spread of axial material can be avoided by attention to the forging technique, for example, by leaving a thick centre boss or by punching out the centre of the blank prior to final flattening followed by forging in such a way as to force material back into the centre of the disc.

Bearing in mind these difficulties the ingot maker can, by careful attention to ingot design and casting conditions, do much to minimize undesirable grain structure, shrinkage, and segregation and thus provide the forgemaster with as sound and homogeneous an ingot as possible. Some recent developments which indicate, however, a radical departure from established practice and which, it is considered, may play a leading part in the future production of heat-resisting forgings will now be considered.

Recent developments

Difficulty is often experienced in working highly alloyed heat-resisting steels because the material is inherently hot-short or non-ductile. Hot shortness may be due to several factors such as contamination with elements such as tin, an excessively high oxygen or sulphur content or it may be related to the chemical balance in the alloy and its influence on the proportion of high-temperature ferrite and austenite. It has been claimed[11] that improvements in hot workability are obtained in many cases by the addition to the molten steel of small quantities of Mischmetall (principally a mixture of the rare earth elements cerium and lanthanum). However, the results of production trials carried out in Britain with Mischmetall additions appear to be far from conclusive, and further work seems necessary.

Whilst much thought has been given to the design of forging ingots in order to produce as sound a product as possible, serious consideration has been given recently to the production of cast shapes, other than conventional ingots designed specifically with a view to the subsequent forging operation. As an example, reference may be made to the problem of producing large Nimonic ring forgings. In this case cast ring blanks have been produced by the centrifugal casting process and

Series on heat treatment

Liquid metal and salt baths

A. D. HOPKINS, M Sc, A I M

The heat treatment of steel in liquid metal and salt baths has many advantages. The author considers five classes of bath—lead, cyanide containing salts, neutral salts, nitriding, and the ' Sulfinuz ' process. This is the fifth of the heat treatment of steel lectures given at the Wolverhampton and Staffordshire College of Technology. The author is a metallurgist in the Heat Treatment Section of the Technical Service Department of the General Chemicals Division of I C I Ltd

LIQUID BATHS have extensive application in the heat treatment of steel, and it is not difficult to seek the reason for their popularity. Firstly, the equipment is simple and of relatively low capital cost, and is capable of giving a high rate of throughput. Secondly, the metallurgical advantages of accurate temperature control and freedom from scaling, plus, in the carburizing type of bath, the ready attainment of a controlled carburizing potential, are achieved.

Five classes of liquid baths are used: (1) Lead baths, (2) cyanide-containing salts for case-hardening, (3) neutral salts for hardening and annealing, (4) nitriding baths, and (5) the ' Sulfinuz ' process.

Lead baths

Molten lead can be used as a heating medium within the temperature range 350—850°C. Unless the surface is covered with charcoal, the bath becomes decarburizing on account of the solubility of PbO in lead. The use of lead baths is not very extensive, but for the patenting of steel wire, file hardening and the treatment of taps and dies, it is still used widely. The main advantage of the bath is the high rate of heating achieved, but in addition to the tendency for decarburizing, a further disadvantage is that steel parts tend to float.

Case-hardening in plain cyanide baths

The popular and extended use of sodium cyanide in many branches of the engineering industry is primarily due to the superior wear-resistant properties of the cyanide case and the clean, bright finish, in addition to economic advantages. Salt-bath case-hardening differs from box carburizing in that the steel takes into solution both carbon and nitrogen, endowing the parts with superior wear-resistant properties on account of the effect of nitrogen in reducing the ease with which martensite can be tempered.

The chemistry of cyanide baths may be explained in the following way:

When pure sodium cyanide is melted in air, partial oxidation takes place and sodium cyanate is formed:

$$2\,NaCN + O_2 = 2\,NaCNO$$

Sodium cyanate decomposes when heated to form sodium carbonate, carbon monoxide and nitrogen:

$$4\,NaCNO = Na_2CO_3 + 2\,NaCN + CO + 2N$$

This reaction is catalysed by the presence of iron. Some of the nitrogen dissolves in austenite. Carbon monoxide reacts with iron in the following way:

$$2\,CO + 3\,Fe = Fe_3C + CO_2$$

and consequently the part is carburized.

CO_2 also reacts with cyanide to provide further CO:

$$NaCN + CO_2 = NaCNO + CO$$

A further important factor is the catalytic effect of iron in promoting the decomposition of cyanide to cyanate and carbonate.

Sodium carbonate is the end product and therefore tends to build up in the bath. The composition of a working cyanide-carbonate bath is usually: Sodium cyanide 20—50%, sodium cyanate 0·5—3%, sodium carbonate balance. Additionally, baths may contain an alkali metal chloride, but this is a diluent and does not enter into the carburizing reaction.

The ratio of carbon to nitrogen in a cyanide case varies according to: (*a*) bath strength, (*b*) tem-

intermetallic compounds. Against this, however, it should be appreciated that a coarse-grained material possesses inherently better creep resistance than a fine-grained one, so that the concept emerges of an optimum forging reduction for best creep performance. Furthermore, creep performance is seldom used as the sole acceptance criterion for high-temperature components. The designer is also concerned with the more conventional properties of tensile strength, ductility, and impact. It is well established that some of these properties become increasingly direction-dependent with high forging ratios[17] so that, where transverse as well as longitudinal properties are significant, a limit must be placed on the permissible forging reduction. It is evident then that the final selection of the forging technique for any particular component and material must be made with reference to the balance of properties required by the designer. It can safely be said that, in this connection, there can be no substitute for experience.

Acknowledgments

The authors wish to thank their colleagues at Hadfields Ltd and also the following organizations for their generous help and information provided in connection with this paper: Daniel Doncaster & Sons Ltd, The English Steel Corporation Ltd, Thos. Firth & John Brown Ltd, Garringtons Ltd, High Duty Alloys Ltd, William Jessop & Sons Ltd, The Loewy Engineering Co Ltd, Murex Ltd and Rolls-Royce Ltd.

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IRON AND STEEL INSTITUTE

Annual general meeting

THE NEW PRESIDENT of the Iron and Steel Institute, Mr C. R. Wheeler, C B E, was inducted at the annual meeting in London on Wednesday, May 7. Joint managing director of Guest Keen Iron & Steel Co Ltd, and a director of numerous associated companies, Mr Wheeler is also chairman of B I S C (Ores) Ltd. He is a member of the Council and Executive of the British Iron and Steel Federation, and among many other activities, is president of the Institute of Vitreous Enamellers. This month's gathering was the 89th annual general meeting of the Institute. The presentation of medals and awards was made by the retiring president Mr A. H. Ingen-Housz.

Bessemer medallist

The Bessemer Gold Medal for 1958 was awarded to Mr W. F. Cartwright, assistant managing director and general manager of the Steel Division of the Steel Company of Wales Ltd. To Mr W. C. F. Hessenberg, deputy director of the British Iron and Steel Research Association went the Sir Robert Hadfield medal. The Ablett Prizes were awarded to Mr C. E. H. Morris and Mr R. N. Dale, Steel Company of Wales Ltd, for their paper on 'Planning the conversion of a high-lift slabbing mill to a universal mill.' The authors received £50 each.

On Thursday morning, discussions took place on the following papers: 'Carbide precipitation in several steels containing chromium and vanadium,' by A. K. Seal and R. W. K. Honeycombe; 'The effect of tantalum and niobium on the tempering of certain vanadium and molybdenum steels,' by A. K. Seal and R. W. K. Honeycombe; 'The tempering of low-alloy creep-resistant steel containing chromium, molybdenum, and vanadium,' by E. Smith and J. Nutting; 'Low-carbon bainitic steels,' by K. J. Irvine and F. B. Pickering; 'The metallography of low-carbon bainitic steels,' by K. J. Irvine and F. B. Pickering.

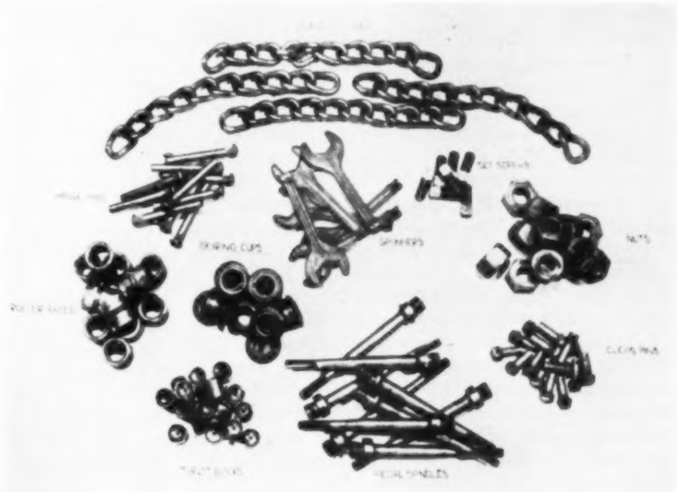
The papers discussed in the afternoon session were: 'Effect of phosphorus on the tensile and notch-impact properties of high-purity iron and iron-carbon alloys,' by B. E. Hopkins and H. R. Tipler; and 'Variation of transformation characteristics within samples of an alloy steel,' by W. Steven and D. R. Thorneycroft.

It was announced at the annual general meeting that H.M. King Baudouin, King of the Belgians, and H.R.H. Charlotte, Grand Duchess of Luxembourg, had graciously accepted Honorary Membership of the Iron and Steel Institute.

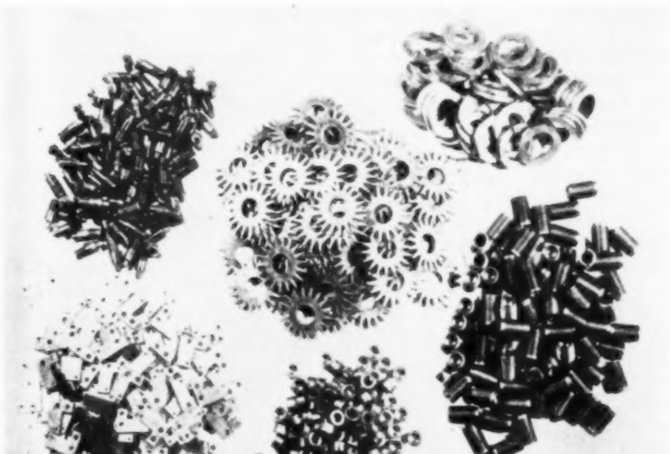
0·01 in, direct hardening gears in En 18 or En 24 alloy steel. The molten salt bath uniformly heats large batches of gears during which time a thin case is conferred. This has the advantage of giving added wear resistance to gear teeth by virtue of the presence of the nitrogen-rich layer.

Salt bath carburizing for deeper cases

Where the necessity for normal grinding arises to correct distortion occurring in quenching, Rapideep is recommended for carburizing. Rapideep is an accelerated cyanide bath containing alkaline earth chlorides which carburizes at a somewhat faster rate than do either cyanide-carbonate baths (40—50% NaCN) or C S 700 baths (25% NaCN). An additional advantage is that the 'glass-hard' zone obtained by hardening cases applied in these baths is approximately 50—60% of the total case depth. Greater amounts of grinding are thus permissible without sacrifice of hardness. The objectionable features of under-saturation or supersaturation, often experienced in



2 RIGHT *Selection of parts treated in cyanide-carbonate salts at 850—950 C followed by water quenching*



3 LEFT *Parts treated in cyanide-carbonate bath. All water quenched except for screws at bottom right of photograph*

perature of carburizing, and (*c*) thickness of carbonaceous covering on the bath.

These three factors are interdependent.

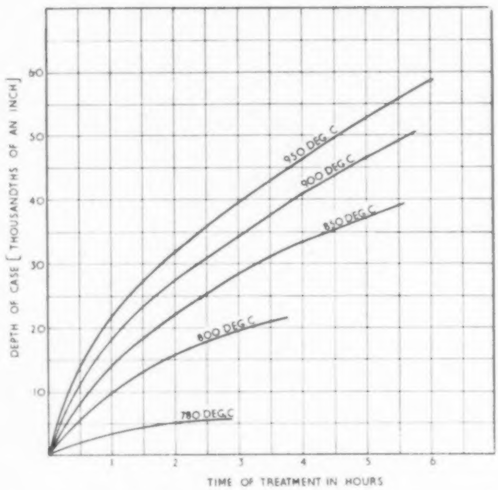
A cyanide-carbonate bath containing 40—50% NaCN working at 900—950°C produces cases with high carbon content and a moderate percentage of nitrogen. With lower cyanide contents, however, the carbon content is less but the nitrogen is increased. A bath relatively high in cyanide but operating at a low temperature will also give a low-carbon and high-nitrogen content.

A cyanide-carbonate bath without the normal carbonaceous cover produces a case containing both carbon and nitrogen, the proportion of each depending on the bath strength and the temperature of carburizing. When the carbonaceous cover is used as is normally recommended, the ratio of carbon to nitrogen is increased.

Table I gives details of percentages of carbon and nitrogen in case-hardening mild steel carburized for 2½ h at 950°C in sodium cyanide-carbonate baths of varying strengths and Table II shows the variation in percentages of carbon and nitrogen contents of a case-hardening mild steel carburized for 2½ h in a 50% sodium cyanide-carbonate bath at different temperatures.

The total depth of case obtained is dependent on the time and temperature of carburizing. Time penetration curves which indicate total case depths produced in cyanide-carbonate baths containing 40—50% sodium cyanide, or C S 700 baths containing 25—30% sodium cyanide and alkali chloride are given in fig 1. The case depths were measured microscopically on treated carbon case-hardening steel specimens slowly cooled from carburizing.

Hardness tests made on cyanide case-hardened bars which have been step ground, show that the immediate surface layers of the case are slightly less hard than the underlying material. This is due to some retention of austenite caused by the nitrogen



1 *Case depths in cyanide-carbonate and chloride-cyanide-carbonate baths*

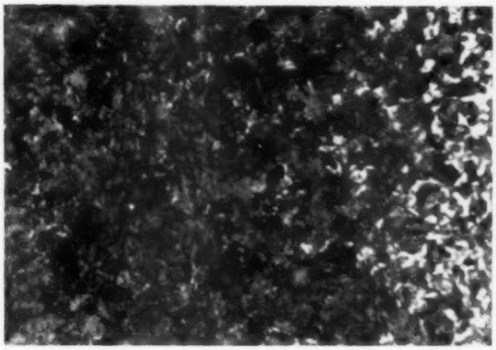
content, which is greater nearer the surface. About one-third of the total depth of case produced in 40—50% cyanide-carbonate baths is 'glass-hard' after quenching. In view of the relatively steep hardness gradient only very light grinding of the case is permissible. (For parts which need to be ground an accelerated carburizing bath such as Rapideep should be employed.) Examples of applications of cyanide-carbonate and C S 700 baths are shown in figs 2 and 3. Though applications of cyanide-carbonate baths and C S 700 baths for skin hardening are far too numerous to be dealt with here, one is of special interest, *viz*, the use of C S 700 for the dual purpose of austenitizing and superficially carburizing, to a depth of 0·005—

TABLE I *Carbon and nitrogen content (%) of mild steel carburized for 2½ h at 950°C in baths of varying strength*

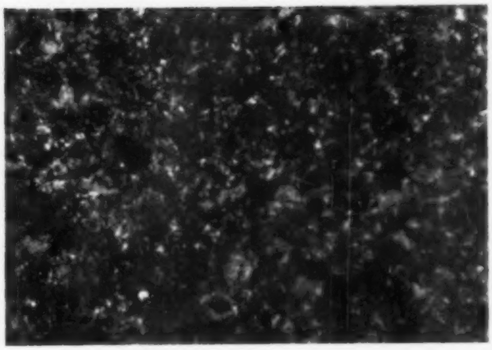
Bath strength	50% NaCN		40% NaCN		30% NaCN		20% NaCN		10% NaCN	
	C	N_2	C	N_2	C	N_2	C	N_2	C	N_2
Cut 1, 0·003 in	0·91	0·11	0·92	0·10	0·76	0·12	0·51	0·16	0·52	0·26
Cut 2, ,,	0·80	0·08	0·78	0·07	0·66	0·08	0·54	0·10	0·41	0·31
Cut 3, ,,	—	—	—	—	—	—	—	—	—	—
Cut 4 ,,	0·64	0·05	0·61	0·06	0·52	—	0·32	0·07	0·31	0·08

TABLE II *Effect of temperature on carbon and nitrogen (%) of mild steel carburized for 2½ h in 50% cyanide-carbonate baths*

Bath temperature	950°C		900°C		850°C		800°C	
	C	N_2	C	N_2	C	N_2	C	N_2
Cut 1, 0·003 in	0·86	0·18	0·91	0·22	0·81	0·21	0·73	0·55
Cut 2, ,, ...	0·86	0·05	0·78	0·21	0·65	0·11	0·26	0·17
Cut 3, ,, ...	—	—	—	—	—	—	—	—
Cut 4, ,, ...	0·74	0·04	0·57	0·06	0·41	0·05	0·20	0·05



5 0·9% *C steel treated in muffle furnace with gas curtain for 2 h at 900°C and then air cooled* ×100



6 0·9% *C steel treated for 2 h at 900°C in Cassel W S* 720 *salt and then air cooled* ×100

While baths of molten barium chloride produce scale-free work, the disadvantages of decarburization are still present, usually to a degree which renders the tool useless unless a considerable amount of material can be ground from the surface. This is often difficult, sometimes impossible, on certain types of tools like form cutters. These difficulties have been overcome by the introduction of Cassel H S 970, which was developed for hardening of high-speed and other steels within the temperature range of 970—1,350°C. The H S 970 salt contains its own regenerator (borax) so that the bath does not normally become decarburizing in service in the way that an unregenerated chloride bath does. So marked is the improvement effected by the use of this bath that final grinding after hardening may often be unnecessary. The dimensions and form are almost unaffected by heat treatment, with greatly reduced risk of cracking.

The plant now widely used is of standard design consisting of salt bath preheating furnaces, a high-temperature salt bath heated electrically, and quenching furnace. The latter may also be used for secondary hardening if the rate of throughput permits.

The technique normally employed consists of:

(1) Preheating the tools to 350—400°C in air. The preheating chamber attachment used on a Cassel furnace is ideal for this purpose.

(2) Raising the tools to a temperature of 850°C approximately in Cassel P S 760 (the preheating salt).

(3) Transferring the tools to H S 970 in a furnace lined with ceramic material and heated by passage of a current through the salt *via* (usually) three electrodes. The temperature control on these baths is very accurate and can be regulated by hand operation of a tap changing switch on a transformer, or automatically.

(4) Quenching into Cassel Q S 540 held at 560—580°C.

(5) Cooling in still air to room temperature.

(6) Secondary hardening in Q S 540.

(7) Cooling in still air to room temperature.

(8) Re-secondary hardening in Q S 540.

(9) Final cooling in still air after which salt is removed by washing.

Although immersion times are not critical and slight over-soaking of high-speed steel in the H S 970 bath does not cause appreciable grain growth, every care should be taken to see that sufficient time is given for maximum solution of carbide and that the temperature of the bath is correctly maintained, because high-speed steels contain tungsten and other carbides which are reluctant to enter into solution in the steel even at the highest temperatures. Overheating is far more detrimental to high-speed steel than is slight oversoaking, for the former produces rapid grain growth and consequent brittleness in a tool, besides the danger of cracking. Times of heating (Table III) are distinctly different from those based on muffle furnace practice.

Secondary hardening is an essential operation if good results are required. It is better, in fact, to submit the tools to two or even three treatments. Care should be taken to secondary harden as soon as possible after the steel has cooled to room tem-

TABLE III *Immersion times in Cassel H S* 970

Hardening temperature, °C	Soaking time per inch of thickest section (min)	Minimum immersion time
1,320—1,340	1½	20 sec
1,270—1,310	1¾	20 ,,
1,220—1,260	2	25 ,,
1,100—1,150	7	10 min*
1,000—1,100	10	10 ,, *

* For hot die steels

box carburizing and gas carburizing, are entirely absent in the Rapideep method. Charges in the Rapideep bath attain carburizing temperature in a shorter time, as compared with the box method of carburizing, and no diffusion period is necessary as in gas carburizing. There are two types of Rapideep in use—Rapideep S and Rapideep H. The former is more suitable for carburizing work which has previously been copper-plated for selective hardening, and in instances where work is to be transferred to a molten bath of 'Cassel' T S 150 for martempering, about which more will be said later. Rapideep H, however, may be employed for both carburizing and subsequent heat-treatment operations, as its composition renders it more fluid at the lower temperature ranges of heat treatment. Also it has a higher degree of solubility in water, thus facilitating salt removal by washing when the work has been finally hardened with an oil quench. While Rapideep S and Rapideep H are composed of similar constituents, their proportions differ in that the working bath of Rapideep S contains 12% sodium cyanide, while the working bath of Rapideep H contains 20% sodium cyanide. The balance is in each instance made up by alkaline earth chlorides which also differ in proportions. The results produced by either bath are, however, identical in respect of penetration rate, composition of case and hardness. Fig 4 represents time-penetration curves showing total depth of case for carbon case-hardening steels carburized in Rapideep S and Rapideep H.

The chemistry of activated cyanide baths is not completely understood, but it is probable that the change in character of the case may be attributed to the formation of barium cyanide:

$$Ba(CN)_2 = BaCN_2 + C$$

This carburizing reaction is frequently referred to as the 'cyanamide shift' and it becomes an increasingly important factor as the temperature is raised. Less cyanate is formed in activated baths and hence the pick-up of nitrogen is less. Consequently the cases produced in accelerated cyanide baths compare closely with those obtained in the best pack carburizing practice. The carbonate content gradually increases as the bath is used and it is necessary to regenerate not only with cyanide but with alkaline earth chlorides.

Neutral salts

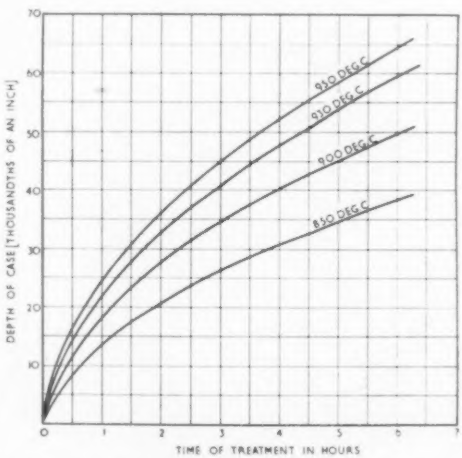
Neutral salts are composed of mixtures of chlorides which in time tend to become decarburizing. However, by regular daily additions of a regenerator the oxides and oxy-chlorides are removed and fall to the bottom of the pot as a sludge, which is dredged before the introduction of fresh regenerator. This simple procedure regularly attended to completely avoids decarburizing.

Interesting comparisons are made by figs 5 and 6, which illustrate the effect of decarburization of 0·9% carbon steel treated in an atmosphere-controlled muffle furnace for 2 h at 900°C and air cooled, and 0·9% carbon steel treated for 2 h at 900°C in Cassel W S 720 normally regenerated with regenerator 'A.' A further interesting feature of Cassel W S 720 is its transparency which is normally maintained when the bath is free from oxides. The high solubility in water is of considerable advantage where steels treated in Cassel W S 720 are oil quenched and need to be washed free from salt and oil.

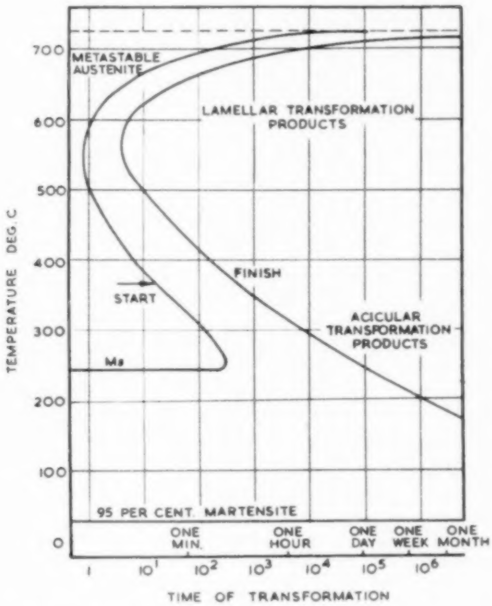
The neutral salts are used widely for annealing, normalizing or hardening of carbon and alloy steels to avoid decarburizing and scaling, but in this section mention may also be made of the low melting mixtures of nitrite-nitrate which are used at temperatures up to 550°C for tempering and low-temperature stress relief operations. These salts are also used for the heat treatment of aluminium and its alloys.

Neutral salts for the treatment of high-speed steel

The question of decarburization and oxidation was frequently encountered in the hardening of high-speed steels. This problem became particularly acute when steels containing higher proportions of molybdenum and cobalt were developed as substitutes for 18/4/1 steels during the second world war. The problem of preventing scaling and decarburization is aggravated with these materials because of the high temperatures involved, and salt bath methods were recognized as being essential for the satisfactory treatment of each materials.



4 *Case depths in activated cyanide baths*



7 *Simple T—T—T curve*

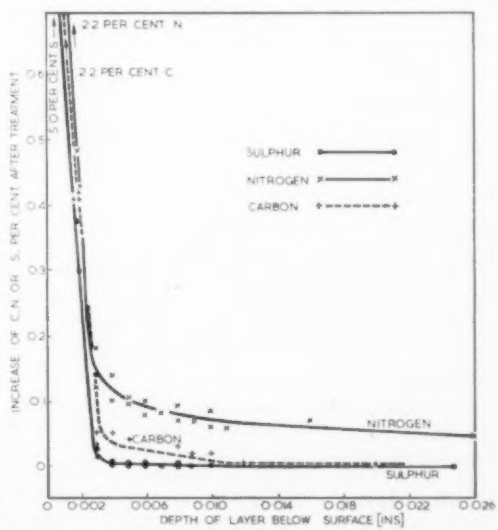
by the steel. Cyanate is more stable at relatively low temperatures, so that by operating an aged cyanide bath at temperatures not exceeding 550°C the proportion of nitrogen absorbed by the steel can be increased and the amount of carbon taken into solution at these temperatures is negligible. The use of nitriding baths is not completely satisfactory for the production of deep nitrogen cases such as those obtained by the 48—96-h gaseous ammonia nitriding process, but for high-speed and certain other high-alloy steels an extremely hard nitride case can be produced which improves to a considerable degree the life of a variety of keen edge tools such as taps, chasers, broaches, reamers, etc. The time of nitriding is dependent upon the nature of the parts and varies from 5—90 min. The customary treatment time is of the order of 20—30 min, but depends on the design of the tool and its service conditions.

The Sulfinuz process

The latest salt bath process to be developed is Sulfinuz treatment, which improves seizure and wear-resistance. The bath employed is essentially a cyanide bath containing sulphur compounds maintained at 500—600°C. The normal treatment consists of heating for 2 h at 570°C. The surface of the part becomes impregnated with sulphur and nitrogen. All of the sulphur and most of the nitrogen is found in the first 0·002 in of the surface. The sulphur content of the first 0·001 in is approximately 5%. Whilst the nitrogen in the first 0·001 in is approx 2%, mainly as a white layer of iron-nitrogen compound, diffusion of nitrogen proceeds to a considerable depth in mild steels, the depth of penetration in other steels depending on alloy content and time of treatment. For delicate high-speed steel tools the immersion time may be as low as 10 min. Sulfinuz-treated parts should preferably be lubricated in use, but certain applications have been found where satisfactory life may be obtained in the absence of oil, *e g* pumps for solvents, components used in atomic energy equipment and on aircraft. The variation of chemical composition is shown in fig 8.

To evaluate the improvements in wear and seizure resistance obtained from this process, tests have been carried out using an Amsler wear-testing machine, which enables severe conditions of loading to be applied to cylindrical moving testpieces for prolonged periods in a controlled and variable manner. Table IV shows a comparison of Sulfinuz treatment with various other surface treatments. The Amsler test results showed that seizure occurred after far fewer revolutions with case-hardened, case-hardened and phosphated, or nitrided testpieces than with Sulfinuz treatment. Nitriding followed by treatment in a caustic sulphur solution was also inferior.

The simultaneous absorption of sulphur and nitrogen in the Sulfinuz process produces far better



8 *Variation of chemical composition with 'Sulfinuz' treatment*

perature from the Cassel H S 970 bath, as unnecessary delay in doing so may lead to development of cracks due to quenching stresses, which are more pronounced if the steel has been quenched in oil.

Isothermal transformation

To understand the advantages of salt baths for isothermal transformation of steels it is necessary to discuss heat treatment in relation to the ' S ' curve. The ' S ' curve shown in fig 7 denotes the time at the various temperatures at which austenite, formed at the hardening temperature, transforms to other constituents on cooling to and holding at the temperature indicated.

To harden steel completely it is necessary to cool the material from the hardening temperature sufficiently rapidly to reduce its temperature to the M_s temperature without any other transformation product forming, that is, the cooling curve for the sample must lie to the left of the nose of the curve. If a steel containing 0·9% carbon is cooled to, say, 275°C in less than a second, it may be held at this temperature for over a minute without any transformation taking place. If the specimen is removed from the bath, hard martensite will be formed on cooling without the need for the more drastic water quenching which is well known to cause distortion. This principle forms the basis for the process of martempering or interrupted quenching. The process is limited to thin carbon steel parts or alloy steels of greater section. With alloy steels the rates of cooling during quenching to the M_s temperature can be slower than with carbon steels, whilst still attaining the full hardness because alloy additions to steel generally move the nose of the ' S ' curve to the right. Punches and dies for plastic moulding and die-casting are being successfully treated in this way. The main advantage of the process over water or oil quenching is the reduced distortion combined with freedom from cracking. Martempering is also effectively used in case-hardening. For example, alloy steel parts are case-hardened in Rapideep, transferred to a holding bath at 600°C, reheated to 820°C and then transferred to T S 150 salt at 230°C for martempering, followed by air cooling. The T S 150 nitrate-nitrite bath inevitably becomes contaminated by chlorides which are carried over from the holding bath. Unfortunately a loss of quenching power results from the contamination and, to maintain the efficiency, the contaminant may have to be removed by a salt separator.

Whereas in martempering it is necessary to prevent any products other than martensite being formed, in austempering the formation of bainite which occurs between the M_s temperature and the nose of the curve is deliberately encouraged. For austempering, the parts are heated to the hardening temperature (austenitized) and then quenched into a bath of molten salt held at predetermined temperatures in the neighbourhood of 300°C. The time of holding at this lower temperature depends on the carbon or alloy content of the steel, and should be determined for the particular material being treated. Generally speaking, the time is from about 20 min to 1 h. Again, only thin sections of carbon steel can be treated, but the size of parts made from low-alloy steels is not subjected to a stringent limitation as regards section. Austempering produces parts of a hardness similar to those obtained by normal quenching and tempering, but they possess a higher toughness and ductility. The process is used for typewriter parts, various springs and needles. When springs are treated to the same proportional limit but higher tensile strength, then austempered springs have a higher endurance limit than those treated by other methods.

The process has not found wide acceptance for the treatment of low-alloy steels, because many authorities maintain that the mechanical properties resulting are inferior to those obtained in the quenched and tempered part.

Finally, the information obtained from the ' S ' curve can be put to practical use in softening steels for machining. The normal method of softening, say, alloy steel for machining before hardening, is by very slow furnace cooling from the annealing temperature. The steel is heated in a muffle furnace above the critical point or critical range, then slowly cooled to room temperature. The process is time consuming and may take as much as two days. In isothermal annealing the steel is austenitized by heating above the critical or often in the critical range for medium carbon steels, and instead of cooling slowly the steel is cooled as quickly as possible to a temperature not far below the critical point (on cooling) and held at the temperature until transformation is complete.

For a high-carbon steel the isothermal annealing treatment would be 15 min at 760°C, followed by cooling in another salt bath to 700°C and holding at that temperature for 1 h. After this period had elapsed the steel may be cooled as rapidly as is desired to room temperature. Therefore a process taking under 2 h can replace an orthodox annealing process which would occupy a much longer period, and will yield a product with better machinability. Carbon or low-alloy steel forgings can be quenched direct from the forging dies into a nearby salt bath and held until transformation is complete. The forgings are then water quenched, blowing off the forging scale.

Nitriding

It has already been pointed out that the formation of sodium cyanate leads to the absorption of nitrogen

Table IV *Mild steel testpieces subjected to various surface treatments and tested on an Amsler machine. Testpieces rotated in the same direction at 440 and 400 rev/min respectively using light machine oil as lubricant and loads of 20 kg and 50 kg respectively*

20 kg load (rev)	Surface treatment	50 kg load (rev)
660 seized	Untreated	250 seized
1,000,000 not seized	Sulfinuz treated 2 h at 570°C. Air cooled	429,000 ,,
33,390 seized	Caustic-sulphur bath 50% NaOH, 5% S: 1 h at 100°C	2,000 ,,
243,700 ,,	Phosphated for 20 min at 100°C	3,000 ,,
20,000 ,,	Pack carburized to 0·050 in, hardened, ground to remove 0·010 in	1,500 ,,
250,000 ,,	Nitrided in aged cyanide bath 2 h at 570°C. Air cooled	30,750 ,,
28,760 ,,	Nitrided as above + caustic sulphur treatment	10,000 ,,
50,750 ,,	Pack carburized hardened, ground and phosphated	10,000 ,,

wear resistance than nitriding followed by sulphiding. It is considered that the difference between these two types of process may be sought (*a*) in the fact that penetration of sulphur occurs in Sulfinuz treatment to a greater depth and (*b*) that the presence of sulphur compounds in the Sulfinuz bath enhances the nitriding potential of the salt and for equal times of treatment results in a case which is richer in nitrogen.

Applications of the Sulfinuz process are now found in many industries such as textile manufacturers, bearings, conveyors, small petrol engines, nut and bolt makers, wire drawing machinery, etc.

Conclusion

To sum up, salt bath methods of heat treatment possess the following definite advantages: (1) Clean finish on treated parts, (2) absence of scaling, (3) reduced distortion, (4) uniformity of results obtained, and (5) ease of control and simplicity of operation enabling relatively unskilled labour to be employed.

For the newer processes of martempering, austempering and isothermal annealing, salt baths permit the processes to be carried out in a simple way, the only alternative to which would be the use of baths of molten lead or tin which, in addition to the high capital cost, present other practical difficulties such as oxidation and the tendency of the parts to float.

Europe's largest titanium melting plant

The largest titanium melting furnace in Europe came into operation recently at the Kynoch Works of I C I Metals Division at Witton, Birmingham.

This is one of three furnaces supplied to I C I Metals Division by W. C. Heraeus G m b H (Western Germany) for the production of double-melted ingots up to 4,200 lb in weight, by the consumable-electrode arc-melting process. The furnaces were delivered in January and the first 1-ton ingot was produced a little over two months later. Within a few days, an ingot weighing 4,200 lb—the largest to be produced outside the U S—was successfully melted.

The availability of such large ingots offers two important advantages: (1) It widens the scope of fabricating techniques which can be applied to titanium. In particular, it makes possible for the first time the rolling of slab into long-length coils by strip-rolling techniques without the necessity for welding small coils together.

(2) It increases yield by decreasing surface/volume ratio. Any reduction in process scrap is, of course, a most significant factor, because titanium is still a relatively expensive metal.

Furnace features

The new equipment embodies several interesting features. The melting current employed is higher than has before been used for this purpose in Europe, which facilitates more complete melting and results in ingots of improved homogeneity and better surface quality. The furnace will normally operate with a high-degree of vacuum, a pressure of under 10 microns being maintained throughout a melt. Facilities are also provided for melting under a reduced pressure of an inert gas, should this be required.

Particularly useful are features which reduce 'down time' between melts and effect big improvements in furnace utilization. One such device enables the first-melt ingot to be withdrawn into the upper part of the furnace and held in vacuum while the larger-diameter crucible necessary for the second melt is fitted. Another allows the second-melt crucible, containing the double-melted ingot, to be sealed by a plate valve and withdrawn from the furnace for cooling, so that the furnace can immediately be prepared for another melt.

The hazards associated with titanium melting are now understood, and the new installation incorporates advanced measures to ensure safe working. All operations are carried out by remote control and the furnaces are installed in massive reinforced concrete cubicles affording complete protection. In the control room, optical systems give operators a clear view of the furnace interior throughout the melting process. Other instruments record essential technical data at all stages and incorporate a system of fault indication and location. The effect of such protective measures is to allow considerably greater flexibility in melting operations.

It is less than three years since I C I commissioned Britain's first titanium melting plant. Since then, technical knowledge has accumulated so rapidly that the company has twice replaced its entire complement of melting furnaces. I C I is, however, satisfied that furnace development has now achieved stability and that the present equipment will meet all foreseeable requirements for a much longer period.

In 1955, eighteen furnaces were needed for an output of 1,500 tons a year; today, three are sufficient to produce over 2,000 tons a year.

Computers in the steel industry

Electronic digital computer in use at B I S R A

B I S R A Operational Research Department's conference

A ONE-DAY CONFERENCE on 'Computers in the steel industry' was held by the British Iron and Steel Research Association last month.

Organized by the B I S R A Operational Research Department, the conference was directed by Mr F. H. Saniter, Director of Research of the United Steel Cos Ltd. Four papers were given.

Over 150 engineers and technicians attended, together with a number of managerial and accountancy executives who were interested in administrative applications of the electronic computer. Many of those present subsequently attended demonstrations of the 'Pegasus' electronic computer recently installed by B I S R A at its Park Lane offices.

The Operational Research Department is investigating possible applications of the computer in the iron and steel industry as a production and administrative aid. The association will be able to advise the iron and steel industry on the applications, installation and operating technique of this new development. It is also expected that B I S R A will eventually be able to make the apparatus available to steel firms who have specific problems susceptible to solution by the apparatus.

'*Experience in using a computer for payroll*,' by J. S. Pugh of Guest Keen & Nettlefolds (Midlands) Ltd, Screw Division.

Mr Pugh described how the management of Guest Keen & Nettlefolds (Midlands) Ltd decided in February, 1955, to place an order for an HEC 4 general-purpose computer, manufactured by the British Tabulating Machine Co. Ltd. This decision was reached without prior investigation as to which machine was best suited to their purpose, for it was thought that the experience gained in attempting to apply work to this machine would be invaluable for the future and it was also thought worth while to gain this experience as early as possible. In short, the whole project was looked upon as a pilot scheme for future computer work within the G K N Group of Companies. It was also decided at this stage that the machine should be installed at the Screw Division of G K N (Midlands) Ltd.

Works payroll

Shortly after placing the order it was decided to apply the works payroll of the Screw Division (approximately 4,000 employees) to the computer and in June, 1955, a two-man team was appointed to investigate the existing routines, plan and programme the new procedures, and to make all the necessary layout arrangements for the installation of the machine.

After detailing the procedure used in this appli-

cation, Mr Pugh gave the following conclusions:

'The major step required before any job can become a computer application is that it is necessary to make a fresh appraisal of the problem under investigation, to consider not only what it is—but what it ought to be. The examination of any commercial problem in this way calls for a long and painstaking enquiry and if anything has been gained from our experience it is to reaffirm that this examination is one for full-time methods specialists and cannot be carried out on a part-time basis by the accountant or office manager and his staff.

'The writing of computer programmes is again a specialist job and selection of the right people to do this kind of work is most important. It is difficult to sum up in a few phrases exactly what is required when selecting personnel for this work and all we can say is, look for someone of about G C E standard who thinks in terms of figures and symbols and is good at solving crossword puzzles. We do not feel that mathematicians are essential for programming commercial work on this machine, although one is most likely to find the essential necessary qualifications in a mathematician.

'Finally, we do feel that the use of the computer will be justified from an economic point of view and already staff savings are gradually taking place as more and more work is transferred to the computer.'

'*A simulation of melting shop operations by means of a computer*,' by R. Neate and W. J. Dacey (Steel Co of Wales Ltd).

The authors explain first of all the fundamental basis of the simulation technique.

The time taken to perform any one of a sequence of industrial operations will normally show a certain amount of variation which is in no way connected with the times of other operations in the sequence. For instance, some if not all of the variation in the refining time of an open-hearth furnace cast cannot be related to variations in the other components of the tap-to-tap time. This unpredictable or random variation is the cause of considerable difficulty when carrying out operational studies, and particularly when trying to estimate what will happen under some postulated set of conditions which cannot be studied directly.

When an industrial organization expands or undergoes development, the management is faced with the task of ensuring the best possible matching of all the items of plant in a works, and this usually involves making an estimate of how a number of units will perform when they are grouped in some way as yet untried. A typical problem is an estimation of the number of soaking pits required to handle ingots from several steelmaking shops and to ensure the supply of hot steel to a primary mill. This problem would be fairly easy if the times involved were constant, but as is well known, the arrival of steel at soaking pits normally follows a most irregular pattern.

Many problems of this nature can be solved by a technique known as 'queueing theory,' provided that the variations of times involved can be expressed in suitable mathematical form. This theory treats the situation as one in which there are customers (*e g* ingot trains arriving at a stripper bay) and servers (*e g* stripping cranes), and a queue forms whenever there are more customers requiring service than there are servers. The queueing time may be a measure of production time lost when plant or equipment is not able to meet the demands made upon it. For complex queueing situations, such as in the soaking pits problem given above, queueing theory in its present form is inadequate and cannot be used except perhaps by making sweeping assumptions which may cause doubt to be cast upon the realism of the result.

There is, fortunately, another technique which is remarkably flexible, and which can deal with almost any queueing situation, no matter how complex.

The performance of a system can be studied by simulating the operations of the system over a suitable period of time. Certain characteristics of the system such as the code of rules governing its operation, and data relating to its operational times, must be available. Since, however, the times are variable, this data is in the form, not of single values, but of frequency distributions compiled from either routine records or from special observations of the plant concerned. A frequency distribution of operational times shows how frequently, in practice, these times occurred within certain time ranges which are sub-divisions of the total range of variation. If it can be established that the times are not related to any other times occurring in the system, then it is permissible in performing a simulation to derive such times by sampling at random from the frequency distribution. This technique, depending as it does on the laws of chance, is known as the Monte Carlo method.

The result required from the simulation may be the total number of operations in a certain period of time (*e g* number of ships unloaded at a port in a year) or the extent of lost production time (*e g* proportion of time when a slabbing mill is idle because no hot steel is available from the soaking pits). The accuracy of the estimate is governed by the length of time which is simulated, since the longer the simulation carries on, the more the effect due to variation in times and to interaction of the various lines is smoothed out. This illustrates a major disadvantage of the Monte Carlo simulation

method. A complex situation of the type described for the case of soaking pits would mean a simulation involving many weeks of tedious plotting on a very complicated chart, and the result would then apply only to one set of conditions. An investigation of new conditions would involve a repetition in full.

In the past, these factors have restricted the size of problem which has been practicable, but now the electronic computer, with its high operating speed and large storage capacity, has helped considerably to ease this restriction.

The authors then go on to show how a typical operational problem is being tackled by this alliance of Monte Carlo method and electronic digital computer.

Oxygen enrichment problem

The problem originated from a trial carried out in May, 1956, to determine how the operating times of a 100-ton open-hearth furnace were affected when the preheated combustion air was enriched with oxygen during the charging period. The optimum degree of enrichment had been found from previous tests to be about 30,000 cu ft of oxygen per hour for an air rate of 550,000 cu ft/h. The corresponding fuel rate was about 300 gal/h of oil or pitch augmented by 15—20,000 cu ft/h of coke oven gas. It should be noted that the results were obtained for one furnace in a particular melting shop, and cannot be expected to have general application.

An analysis carried out on the routine furnace data for the trial period showed that the use of oxygen enrichment had caused an increase of about 20% in the production rate of the furnace. The possibility of increasing shop production by using oxygen enrichment prompted the management to ask for an estimate of the shop's production capabilities when using the technique on a wider scale. It was unlikely that a proportionate increase could be obtained because of the limitations imposed by ancillary equipment and by congestion delays.

Any estimate of future shop production must be based upon assumptions regarding factors which are dependent upon the operating policy in the shop or in the works as a whole. Consequently the problem was considered to be that of estimating the production rate of the shop under various sets of conditions.

It was necessary to devise a method flexible enough to permit the study of all the possible sets of conditions which could be envisaged. A mathematical expression for tonnage output which would include as parameters all the factors liable to change would be an ideal method, since to make a new estimate for changed conditions would merely mean a re-evaluation of the same expression with different values for some of the parameters.

Unfortunately there is no adequate mathematical technique for dealing with so complex a plant as a melting shop. This might not be so if it were permissible to consider parts of the shop separately, but there are good reasons why this cannot be done. A melting shop is an operational unit where undesirable but unavoidable interactions occur between furnaces which must share the same equipment. By having the services of a charging crane one furnace may be denying such service to another furnace. Again, a delay to a furnace caused by an inadequacy of cranes in the casting bay may have effects in the scrap loading bay, since the time at which the furnace next requires scrap will also be delayed. It was therefore necessary to resort to the Monte Carlo method. In order to render the method practicable, it was necessary to find a means of mechanizing it or, better still, of making it completely automatic, and the electronic digital computer appeared to have the necessary facilities.

'*The use of a computer in a rolling mill office*,' by R. G. Massey (B I S R A).

In his paper, Mr Massey describes work carried out by the Operational Research Department of B I S R A into the feasibility of using electronic computers and similar associated equipment to assist in the work of a rolling mill office.

A rapid initial survey was made by B I S R A, the chief result of which was the realization that progress with the new mills was so far advanced that it would not be possible to carry out the detailed programming involved, and install a computer in time for the opening of the new mills. The required increase in clerical labour would thus have to be obtained. The study did indicate, however, that a computer could be expected to carry out at least the majority of the work of the office and that a much reduced staff would then be sufficient. This meant that more elderly people could be recruited so that by the time the computer system was installed they would be reaching their normal retirement age.

Computer-controlled hot saw

One of the important aspects of the mill office work is the progressing of production line information against the orders actually placed on the mills. When considering the use of a computer in the mill office, the allied problem of collecting information from the production line and presenting it to the computer automatically was also studied.

The key point in the production line from the point of view of information flow is at the hot saws. Here it is necessary to combine information about the steel being rolled with information about the actual bar being cut or, in more specific terms, the cast, ingot and bloom number, the steel quality,

1 *Even though extremely hard, micrograin nickel is not brittle. It may be bent considerably without cracking, is therefore easily fitted around compound curves or re-entrant shapes*

Micrograin nickel

MICROGRAIN NICKEL, a new type of material which is extremely hard, yet flexible, has been developed by Metachemical Processes Ltd. Resistance to abrasion and impact of this metal is unusually high, better than those of softer types of nickel, nickel deposited from solutions containing organic addition agents, or stainless steel.

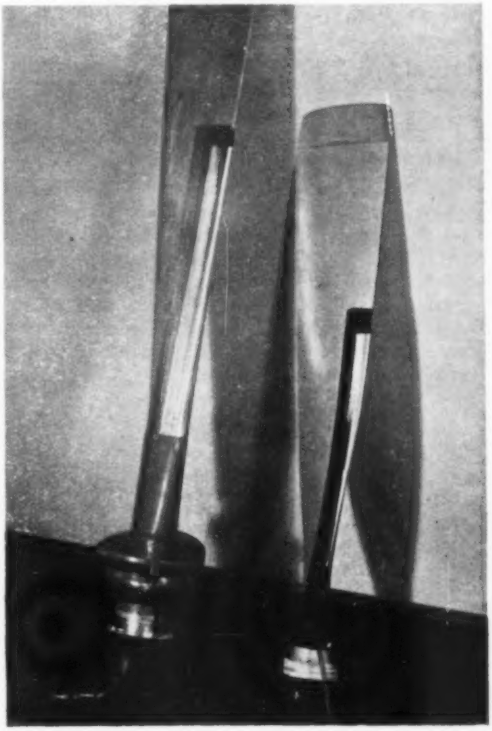
Electroforms of micrograin nickel are currently being proved on the leading edges of aircraft propellers, where they guard the delicate de-icer elements against rupture due to impact with hail, or stones during landing or take-off. Wings of aircraft or missiles can similarly be protected against abrasion, which becomes an ever more burdensome problem as speeds increase.

Tests conducted on a number of Viscount propeller blades show the advantages of protecting the de-icers with a micrograin nickel electroform. While propeller tips were travelling at supersonic speed, batches of pebbles and rocks were sent down a chute, directed at the centre half of each propeller. Four different sizes (fig 2) were used, each taking about 2—3 secs to go through. Fig 3 shows a stainless-steel blade after the first two batches had passed. Fig 4 shows a propeller with a micrograin nickel electroform. Although after all four runs the electroform had also been dented, the de-icer elements embedded in the rubber still functioned; they had been knocked out after the second run in propellers with other types of protective sheaths.

According to studies conducted by H. Denis Hughes and R. W. Lewis, the superior properties of the nickel electroform stem from the very fine grain size deposited electrolytically. Although a standard nickel sulphate bath at conventional pH and temperature is used—without organic addition agents—grain size is so minute that to date no method of etching the deposit for micrographic analysis has been found. The discoverers of the process have established that the fine grain is due to the characteristics of the electrically conductive plastic sheet on which the nickel is deposited.

Method of production

To make a micrograin nickel electroform, a master mandrel of metal is first prepared, by casting from the contours of the propeller, wing, or other surface to be protected. An electrically conductive



2 *To protect de-icers against rupture by hail, or stones thrown up during take-off and landing, protective sheaths are cemented over rubber-embedded elements. Micrograin nickel electroforms, shown here on two types of blades, fit more exactly, are more flexible and impact resistant than equivalent protectors shaped out of stainless steel*

the section and the gauge of the steel section have to be combined with the order number and length of each particular bar as it is cut. Since it is not possible to label hot steel in any satisfactory manner, it is necessary to have, in addition to the production line flow, an information line flow corresponding to it.

A system has been designed by B I S R A whereby the information about each section is put into a storage system by means of either manually or automatically operated keyboards and press buttons at each of the important work points, *i e* the soaking pits, the primary mill, the primary shears and the secton mill. Provision is made for rejection of ingots or blooms at any stage.

This system still leaves the decision to the sawman as to the order in which to cut the individual customer's bars from the hot section so as to minimize wastage. A system for doing this automatically by means of a computer has also been studied.

It has been found that the optimum selection would require much more time for determination than is available between successive arrivals of sections even for a digital computer and thus certain simplifications have been introduced. This has made it possible on 'Pegasus' to make a selection from up to 200 available bars and print out the selection in under 10 sec, the selection averaging about $\frac{1}{2}$—1% wastage. It is considered that this probably represents sufficient saving to justify the purchase of a special-purpose computer to control the saw.

'*Training for computers*,' by D. G. Owen (United Steel Companies Ltd).

While computers remained in research establishments and were devoted solely to evaluating mathematical formulae, training was a straightforward question of teaching scientists how to use them. Now, however, they are coming into industry, and the problem facing industrialists is a very different one.

It is partly a matter of training programmers, but much more a problem of fitting into the technology of production and management a new concept with which as yet only relatively few people are familiar.

The solution proposed by the author is that steel companies should appoint senior officials to initiate and direct the lengthy investigations which necessarily precede the introduction of computers to either office or production-line work.

LETTERS *to the Editor*

R-F induction heaters

SIR: It is always rather trying to be faced with an article such as that by Ellis on radio-frequency induction heaters (METAL TREATMENT, April, 1958, p 145) which is studded with half-truths or worse, and especially when the impression left on the reader is a quite erroneous one.

On the technical faults I make no comment, in the belief that those who read them will appreciate them for what they are, and those who can't appreciate them won't read so far. I would like, however, to say something on the state of the radio-frequency heating art and the efforts of the generator manufacturers who have fostered it. Both have been given scant tribute by Mr Ellis.

The customer for R-F induction heating who solves, by his own technical resources without aid from the generator maker, the problems of its use, is unfortunately a mythical pipe-dream figure whom we would all like to see materialize and multiply. In actual experience every potential user demands a convincing demonstration, usually on his own components, of the efficacy of the method and the advantages he is likely to gain from its use. He expects the generator maker to do this and to solve the problems involved in so doing. Many customers with, from their own standpoint, commendable precaution, put out the same problem to several suppliers, only one of whom can eventually hope to recover even a part of his costs by making a sale.

No, sir, every generator manufacturer is involved in heavy costs for the skilled technical effort involved in solving customers' problems which rank among the highest of his considerable overhead charges. This situation has persisted for years whilst the induction heating technique has gradually established itself as an everyday manufacturing process: let due tribute be given to them for it.

In spite of these expensive customs, no maker has yet had the nerve to ask £500 per kW (quoted by Mr Ellis) except maybe for some custom-built special equipment or other, and an exceptionally low output of a few hundred watts. Generators usually range from some 2 kW at the lower end (costing about £300/kW) to 35 kW output (costing about £85 kW), though, of course, larger units are not uncommon, the price per kW falling off progressively as output increases.

'Experience,' Mr Ellis tells us, 'has shown that induction heating is only economic in a small proportion of metal heating operations.' With a mental reservation on the smallness of small, I would reply that of course it is, just as spot welding plays a part in only a small proportion of metal jointing operations, or axle-grease in a small proportion of lubricating problems. Let us be more precise. There are certain fields of metal heating in which induction heating plays a big and increasing part; there are others where it plays no part at all. Its broad advantages and limitations are clearly known to the generator makers, and more confidence by potential customers in their knowledge and experience would be a fine thing for the future of the art.

One thing is certain, whoever might have been the misguided ones responsible for the 'extravagant claims' now apparently happily exposed, it was not the generator makers. They have always taken special care to avoid inviting 'Aunt Sally' enquiries which can only add to their extensive technical and financial loads with little or no hope of success.

M. O'C. HORGAN

General Electric Co Ltd,
Magnet House,
Kingsway, London, W C 2.
May 1, 1958.

An unusual design of aircraft hangar doors

New 'wing hangars' introduced at London Airport

SINCE MOST ROUTINE CHECKS and maintenance required by today's airliners are carried out on the forward part of the machine, and since economy of operation is as important in air transport as in any other business, British Overseas Airways Corporation have recently introduced the 'wing hangar' at London Airport. This development, which is new to Britain, encloses only the forward portion of each aircraft, leaving the whole of the tail unit protruding, thus economizing on hangar space and the cost of building. By having sliding doors recessed to embrace the fuselage, the hangar can be completely enclosed while work on the aircraft proceeds.

The doors themselves are of interesting design and provide an unusual example of metal fabrication. There are 48 altogether, 24 on each side of the hangar, which is bisected by a central dividing service hall; 10 of the 24 are motorized and 6 are made with a suitable aperture for the tail enclosure unit.

Each door is 32 ft high, 23 ft 6 in wide and 1 ft thick and is provided with generous windows; a wicket door is provided in each of the motorized doors. The doors forming the tail enclosure units are fitted with flexible fabric gaskets to seal the gap between the doors and the fuselage and yet permit the aircraft a fair degree of movement during servicing. When these units are not in use the apertures can be closed by hinged flaps.

The guide wheels run in brackets fitted to the top of the door frame and the main wheels are housed in a fabricated chassis forming an integral part of the frame. The chassis of the motorized doors is strengthened to carry a 2-h p electrical power unit, fluid drive and clutch mechanism.

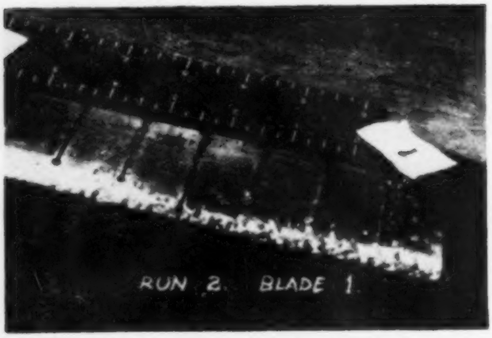
The framework of each door is constructed of steel channel section 12 in by 3¼ in by 10 s w g, cross-braced with a similar section having lightening holes to reduce weight, and use is also made of lattice-type members. The whole was electrically welded. To facilitate handling, the framework was constructed in three sections which were bolted together using gusset plates slotted through the main channels.

Cladding is of aluminium: Noral Mansard sheet 0·036 and 0·028 in thick (20 and 22 s w g) is secured to both sides of the framework by 'pop' rivets and an extruded 'top-hat' section in Noral B51SWP alloy is used to cover the bolt heads so as to give a neat finish. To prevent reaction between the steel and the aluminium, the framework was given phosphate treatment followed by a zinc chromate dip and, in addition, the aluminium surfaces that were to make contact with the steel were coated with a bituminous paint.

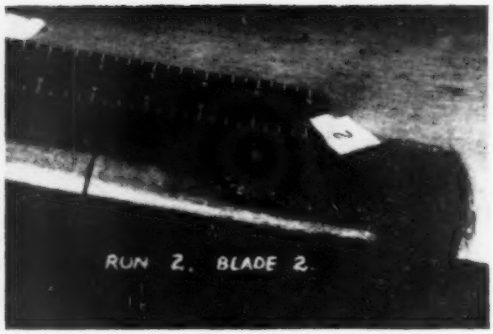
Aluminium, in the form of flat sheet in Noral 3S alloy, half-hard, in thicknesses ranging from 0·064 in (16 s w g) to 0·125 in, was also used for cladding the wicket doors and the hinged flaps that cover the fuselage aperture when required.

Production and assembly problems

It is estimated that the assembly of each door required altogether about 450 ft of welding, which was used not only for the main framework but also



3 *After run 2, stainless steel sheath looked like this. Micrograin nickel electroform, applied to another blade in the same run, fig 4, shows little damage and has kept heating wires in de-icer intact*



4 *After run 2, micrograin nickel electroform shows very little stone damage. Its counterpart of shaped stainless steel has been severely dented, and de-icer elements embedded in the rubber are no longer functioning*

plastic coating, several mil thick, is then applied. After a flash coating of copper has been deposited, the unit is immersed in the nickel plating solution, and left until the desired thickness has built up. The propeller protectors come out ' right ' naturally, *i e* with a heavier thickness (about 0·025 in) at the leading edge, tapering off to 7 mil at the trailing edge.

Compressive stress

Another factor which leads Hughes and Lewis to believe that this is a different type of nickel is that the finished electroform is under compressive stress, whereas most electrolytic nickel deposits show tensile stress. In fact, the compressive stresses set up are so noticeable that care must be taken to prevent cutting of the masking tape at the trailing edge, which would allow solution to enter between the mandrel and the plastic interlining, spoiling the piece.

Brinell hardness of the new type of nickel is up to 600, yet, as shown in fig 1, it may be bent easily, without fear of cracking. Therefore, even shapes with re-entrant surfaces may be plated on the mandrel, removed, then closely fitted to the finished product. The i d circular intake cowl of a jet engine, tapering toward the inside, is one such application.

Applications

At present, principal applications are in the aircraft industry, though other applications will no doubt come along. Boat propellers, for example, may be protected against cavitational erosion. Kitchen counter tops and splash boards, instead of the usual stainless steel, may some day be thin layers of micrograin nickel. Knee-holes in desks, always a point of wear, can be protected against bumps from chairs by narrow strips of this material. And it is not too far-fetched to propose that automotive bumpers, instead of needing laborious grinding, polishing and sealing process prior to chrome-plating, may some day be left rough, and finished with a carefully, exactly shaped electroform. In all these uses, as in the case of propellers, the electroform is cemented into position with an epoxy adhesive, whose bond strength has already been well proven.

New French steel research centre

Last month's opening at Metz

NEARLY 800 PEOPLE from many parts of the world attended the official opening, at Maizières-les-Metz on April 22, by M. Paul Ribeyne, Minister of Industry and Commerce, of the large pilot plant set up by the French Iron and Steel Institute for research into iron and steel industrial processes.

French personalities present included M. Robert Schuman (president of the Assemblé Commune Européene), M. Jean Laporte (inspecteur général de l'administration, prefect de la Moselle), and M. Jean Raty (president of the Chambre Syndicale de la Sidérurgie).

The object of the new pilot plant at Metz is to make possible the processing, outside of iron and steel works, of tonnages sufficiently large to allow full-scale conclusions to be deduced from the results. A full account of the plant will be given in next month's issue of METAL TREATMENT.

POWDER METALLURGY

Second meeting of Joint Group

THE SECOND MEETING of the Powder Metallurgy Joint Group of the Iron and Steel Institute and the Institute of Metals held at Church House, London, in March, was an informal discussion of papers on methods of compacting and sintering powders.

The first paper by T. W. Penrice, of the Production Tool Alloy Co Ltd, was 'Compacting of powders using moulds made from reversible gels.' He described a very ingenious process in which most of the advantages of hydrostatic pressing were obtained and many of its disadvantages circumvented. During compacting, metal powders do not behave as liquids for example, owing to friction between the powder and the die walls, the density of compacts is lower the greater the distance from the advancing ram. The differences in density in the green compact gives rise to distortion during sintering. This difficulty, and others, can be overcome by packing the metal powder into a rubber and plasticine bag which is sealed and subjected to a hydrostatic pressure of, say, 5 or 10 tons. The hydrostatic pressure gives an even green density of the compact, but the process as normally carried out is rather slow and limited to simple shapes.

Penrice has proposed the use of a gel which is a solid when the powder is loaded into the mould space and which acts as a liquid when the pressure is applied. When the pressure is removed the mould returns to its original shape and the green compact can be removed and the mould re-used for some hundreds of pressings. The dimensional accuracy of the process is not as high as conventional pressing, but shapes such as circular tubes can be made which are impossible by conventional pressing.

Direct rolling

The second paper was 'The continuous production of strip by the direct-rolling process' by D. K. Worn of the Mond Nickel Co Ltd. The direct-rolling process was first described by Nalser and Zirm[1] in 1950. It comprises, essentially, the compacting of powder between a pair of rolls into the form of strip, followed by sintering and processing the strip by conventional rolling and annealing processes. The process has increased in importance since the development of hydro-metallurgical and other processes for reducing metals from their ores which give metal powders as their end products, *e g* the Sherrit-Gordon process for nickel.

The rolls used are normally arranged with their axes horizontal and the powder is fed downwards between them. Rather large rolls are needed: 2-ft-dia rolls to produce $\frac{1}{8}$-in-thick strip. The powder is fed into the rolls from a hopper and the correct control of the powder feed is essential to the functioning of the process. Correct feeding is obviously the key to the process and this feeding is difficult since powders with very poor flowability must be used—free flowing powders merely run through the rolls uncompacted. To obtain a reasonable output from the equipment, very long sintering furnaces are needed, otherwise the sintering time is too short. Production rates of about 800 lb/h of nickel strip 12 in wide are under consideration. The production of alloy strip from mixed pure-metal powders is not normally possible owing to the long sintering times required for inter-diffusion. The process is especially attractive for the production of composite strip, *e g* graphited grass sheet for bearing plates in watches and friction materials. Another promising use is the production in thin sheet of materials which are normally too brittle to be rolled.

Direct rolled and sintered strip is usually very porous and is of little practical use, but subsequent cold rolling and annealing gives material structurally indistinguishable from conventional metal.

The third paper was the 'Consolidation of metal powders by hot working within sheaths' by T. Williams of the Atomic Energy Research Establishment. It is claimed that the consolidation of metal powders by hot working in sheaths is simpler than hot die compacting since no protective atmosphere is needed. The sealing of the powder in a sheath reduces health hazards when radioactive or dangerous metals are being worked. The paper demonstrates that a great many methods of hot working in sheaths have been investigated including up-setting, extrusion and hot hydrostatic pressing using lead at 800°C. as the liquid through which pressure is exerted. The main use of the process is the hot working of reactive metals and its widest application is in the atomic energy field.

Vacuum sintering

The fourth paper, 'Developments in vacuum sintering furnaces,' by M. Donovon of the General Electric Co, described in very useful detail the uses and types of vacuum sintering furnaces. For example, furnaces with graphite resistance heating elements giving a working space 10 in dia by 12 in deep are available commercially.

The fifth paper was 'Conditions for effective vacuum sintering and their realization in practice' by Dr Otto Winkler of the Gersetsbau-Anstalt, Liechtenstein. One of the disadvantages of powder metallurgy is the volume of gas which can be chemically and physically absorbed on the large powder surface. Dr Winkler discussed the removal

continued on page 212

for the attachment of glazing bars, cladding stiffeners and other parts. Welding and the work of assembling the three sections had to be precisely done because close tolerances were specified throughout (for example, the overall frame was to be $\pm \frac{3}{16}$ in dead flat); recourse was therefore made to special jigs.

The size of the doors raised further difficulties in fabrication, transport and erection. To enable the whole 32 ft by 23 ft 6 in framework to be turned over after cladding had been completed on one side, a special jig was constructed capable of allowing the frame to swing completely over while suspended from the 40-ft jib of a mobile crane; the jib itself was back-stayed to prevent overturning.

Transport was difficult because, although the works of the fabricators, Morfax Ltd, are situated at Feltham, little more than a mile from London Airport, the doors were a few inches wider than the road at some points and while they were being transported in the flat, supported by a special bolster, the lorry had to 'zig-zag' between the staggered lamp-posts. Due to the enormous overhang it was necessary to travel at a very slow speed on all parts of the route.

Erection was difficult because the roof of the hangar, taking the form of a cantilever of 116 ft span, would not allow the suspension of any fairly heavy load from its free extremity; moreover, since the doors are, in some measure, of stressed-skin construction, there were few points at which they could be lifted. These difficulties were resolved by first supporting the head-box structure, containing the guide beams, on steel poles and then raising the door by means of hand-driven winches, with chains attached to temporary lugs secured to the top of the door, and a fork-lift truck using a special attachment secured to the bottom. In this way the door was manœuvred on to its rail track, then the lifting lugs were removed and the guide wheel brackets attached.

High mobility of doors

The completed doors, weighing about 3 tons each, move easily on their tracks, one man having no difficulty in propelling three of them coupled together. This is due both to the precision of the assembly and also to saving weight as far as possible by the extensive use of welding and the application of aluminium for all but the structural members. Altogether some 24 tons of aluminium, averaging about half a ton for each door, were supplied by Northern Aluminium Co Ltd.

A further, no less important, advantage of the use of aluminium is that it will last for very many years without the need for painting or other maintenance. Thus the economies that were in the main responsible for the unusual design of the hangar will be upheld over the years by the aluminium's durability.

The consulting engineers were Bernard L. Clark & Partners, who designed the doors in co-operation with Mr L. B. Haley, chief civil engineer to the British Overseas Airways Corporation. The fabricators, Morfax Ltd, were also responsible for erection and electrical installation.

Powder Metallurgy

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of these gases during vacuum sintering. Vacuum is not always an advantage—it is a disadvantage if oxygen is to be reduced by hydrogen but a great advantage if the reduction is to be by carbon.

The sixth paper was 'The pressureless sintering of loose beryllium powder,' by T. R. Narrett, G. C. Ellis and R. A. Knight of the Atomic Weapons Research Establishment. These authors describe what, at first sight, appears to be a very roundabout process of melting flake beryllium powder, machining the ingots into swarf, ball milling the swarf and then sintering it without pressing in graphite moulds. However, the process has a number of advantages which amply justify its use. The powders produced shrink very consistently during sintering. Sintering is carried out by high-frequency heating *in vacuo*. Bars and rectangular blocks can be made as well as simulated fuel elements of uranium oxide with a sintered beryllium skin. The sintered density is about 98% of theoretical after 12 h at 1,220°C. The powder-metallurgy process gives a finer grain size and thus more ductile material than vacuum melting.

The last paper was 'Zone sintering,' by T. Amtill and M. Gardner of the Atomic Energy Research Establishment. The paper describes a method where long compacted articles are sintered by passing a furnace along them. It is not very surprising that the process works for rectangular compacts of metal but it is certainly surprising that the process works for alumina-base refractory tubes containing 94% of alumina. The advantages of the process include the fact that long articles can be made using a small furnace.

The papers were introduced by the authors and there was a useful discussion. There is no doubt that powder metallurgy, especially for reactive metals, is a very lively subject.

Reference

(1) G. Naher and F. Zirm, *Stahl u Eisen*, 1950, **70**, 995-1004.

NEWS

Britain's largest galvanizing line

DESIGNED TO PRODUCE 10 TONS of either galvanized sheet or coil per hour, the new Birlec-designed and built galvanizing line at the Ebbw Vale works of Richard Thomas & Baldwins Ltd is Britain's largest and most modern plant.

Nearly 700 ft in length, 36 ft wide, and 30 ft high, the line takes strip up to 48 in wide. Driven by roller conveyor at speeds of up to 250 ft/min through all the stages of cleaning, heat treatment, pickling, coating, shearing to size, and inspecting, the strip is processed in one continuous operation. Apart from electrical and mechanical maintenance staff only six men per shift are required to control the equipment.

The strip is cleaned by passing through a gas-fired flame-heated furnace after which its temperature is further raised to 1,550°F in the heating section of the reducing furnace by gas-fired radiant tubes. In the following section, which is electrically heated, the strip is maintained at a constant temperature where surface oxide is reduced, and annealing takes place. Entering a controlled cooling section it passes into the galvanizing bath at 950—1,100°F, depending on the requirements of the bath, which is self-maintained at approximately 850°F by the temperature of the strip passing through. Electric heating elements are provided for initial melting of the bath, and boosting during topping up.

The strip emerges with a coating which has an adherence sufficient to withstand drawing and forming operations up to the limit of the steel base, and represents a radical departure from earlier methods of sheet steel galvanizing.

Throughout the line, from entering the reducing furnace to emerging from the zinc bath, a protective atmosphere of dissociated ammonia is supplied to all chambers by the Birlec ammonia cracking plant.

The total electrical rating is approximately 1,000 kW plus 50 kW for each of the two ammonia dissociators. For the gas-fired sections, coke-oven gas with a gross calorific value of 500 B T U/cu ft is used, the flame heater taking 18,000 cu ft/h and the reducing furnace 21,000 cu ft/h.

Honeywell-Brown gas and temperature control equipment has been used throughout.

Tonnage oxygen plant for the gas industry

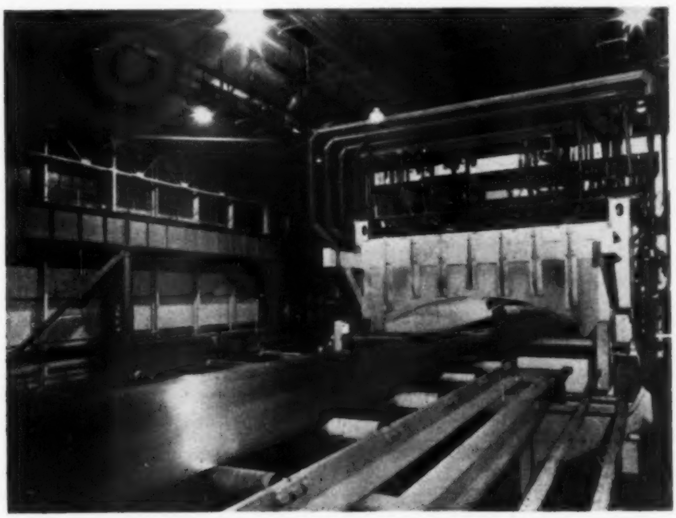
The North Western Gas Board will be the first Gas Board in this country to install a tonnage oxygen plant. The oxygen plant, which will be installed in the Board's new hydrogenation plant at Partington, near Manchester, will be capable of producing nearly 63 tons of oxygen per day. The oxygen will be used for the partial oxidation of oil for the purpose of producing hydrogen which will be used to hydrogenate further quantities of oil in order to produce town's gas. Later, coal will be used as the raw material.

The contract for the plant was placed with Air Products (Great Britain) Ltd, by Humphreys & Glasgow Ltd, who are the main contractors.

One of the major factors considered was the oxygen compression system, which features liquid-oxygen pumps for delivering the oxygen under pressure. This system dispenses with the need for stand-by gas holders, and ensures the delivery of oxygen at constant pressure, consistent purity and flow. These conditions are essential for the efficient operation of the partial oxidation plant.

U S A orders British Servo test equipment

Last month Mr Ian Lynas of North Hollywood, California, U S A, gave to Mr Hugh Binyon, instrument sales director, the Solartron Electronic Group Ltd, on behalf of Solartron Inc, Los Angeles, California—the American distributing company of the Solartron Group—an order worth $121,000 for Solartron transfer function analysers, which the Americans acknowledge as 'the



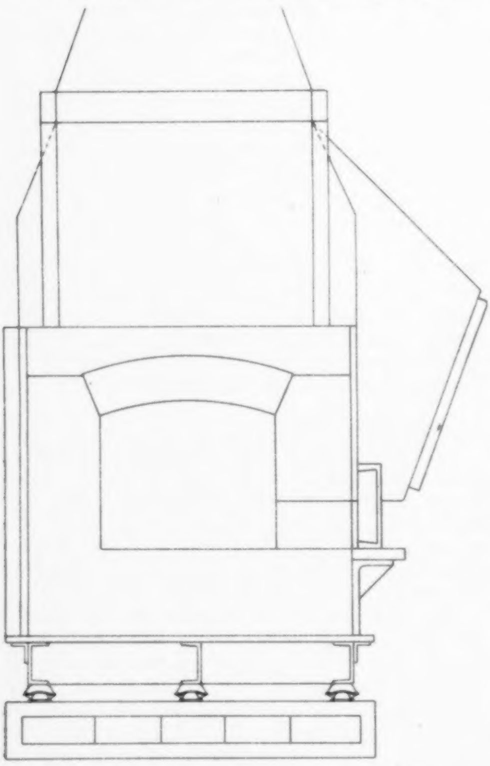
The new galvanizing line at Ebbw Vale is expected to be an important factor in meeting competition for the sale of galvanized sheet in world markets, and orders for the new products have been received from a number of overseas countries

Vibration from forge hammers

THERE IS EVIDENCE to show that the ill-effects of vibration on furnaces can be prevented by the application of anti-vibration mountings and that the cost involved is well repaid by longer life for linings. Indeed, vibration from forging hammers and stamping presses has been known to loosen firebricks in a billet-heating furnace within a matter of days after re-lining has been carried out. Apart from fracturing and dislodging firebricks it deposits flakes of refractory material on the billets and causes scale from them to fall into the furnace.

Whether the furnace or the machine causing the vibration should be flexible mounted depends on circumstances. If the offending installation is a large forging hammer, it is easier to mount the furnace. Hammers give rise to vibrations of large amplitudes so the mountings must be fairly flexible if adequate insulation is to be obtained. On the other hand, mountings which are too flexible render a furnace unstable. It is therefore desirable that the selection of mountings should be left to a vibration expert as mountings with incorrect deflection may do more harm than good.

The 'Cushyfoot' mountings, manufactured by Metalastik Ltd, Leicester, have been applied successfully by leading furnace builders to prevent damage by vibration, and furnaces ranging in weight from 2 to 15 tons have been dealt with successfully. The mountings are easily fixed and designed so that the rubber elements are protected from damage and never lose their resiliency. Further, no maintenance is required.



1 *Schematic arrangement for mounting a 14½-ton furnace*

2 *'Cushyfoot' mounting with cover removed*

Fig 1 shows part of the mounting arrangement for a 14½-ton furnace manufactured by British Furnaces Ltd, the weight being equally distributed over twelve mountings inserted between a fabricated sub-frame and the foundation. With smaller installations, the mountings may be attached direct to the feet of the furnace. Fig 2 is a view of the 'Cushyfoot' mounting with cover removed. The mountings are available for unit loads of from 200 to 3,500 lb.

New slabbing mill for Appleby-Frodingham

Appleby-Frodingham Steel Co, a branch of the United Steel Companies Ltd, have placed an order worth over £500,000 with Davy and United Engineering Co Ltd, for the supply of a new slabbing mill. The mill is expected to come into operation towards the end of 1959.

The existing Davy 42-in slabbing mill has been the primary rolling unit in the Appleby-Frodingham plate mills since 1926. Although still capable of meeting present requirements, the manipulators in particular are not up to the standard necessary to deal with the higher output which will be required from the mill when the company's plate mill modernization scheme is completed next year.

The new 45-in mill will be equipped with universal manipulators and the associated roller tables are included in the order. It will be driven by the original 6,000 h p electric motor through the existing pinion stand. Designed to handle 15-ton ingots, the slabbing mill will have an initial production target of about 17,000 tons a week. Later, output may be stepped up to 25,000 tons a week.

Copper meeting in Geneva

From Great Britain the Copper Development Association was represented at the meeting last month in Geneva by its director, R. B. F. Wylie.

These international conferences have been instituted to further the exchange of ideas on all aspects affecting the general development and usage of copper and its alloys in all branches of industry.

PEOPLE

THE APPOINTMENT is announced of **Mr S. H. Clarke,** C B E, M SC, HON M I FIRE E, as director of the New Research Station now being built for the D S I R at Stevenage for fuel and process research. Mr Clarke is the present director of the Fire Research Station at Boreham Wood, run jointly by the D S I R and the Fire Offices' Committee.

The programme of the New Station will include, as major items, researches on atmospheric pollution, the production of oil from coal and aspects of mineral processing.

Mr S. H. Clarke is 54 years old. After taking his degree while at Nottingham University, at that time the University College, he joined the Forest Products Research Laboratory in 1927. In 1939 he was seconded to the Research and Experiment Department of the Ministry of Home Security. He was appointed the first Director of Fire Research in 1946 when the Joint Fire Research Organization of the D S I R and the Fire Offices' Committee was set up.

The British Iron & Steel Research Association announces that **Mr S. S. Carlisle,** M SC, A M I E E, head of the South Wales laboratories since February 1954, has been appointed head of the Physics Department at B I S R A's Battersea laboratories. In addition he will continue to have an executive responsibility for the South Wales Laboratory as Deputy Head of the Mechanical Working Division (Swansea).

He is to be succeeded at Sketty Hall by **Mr W. N. Jenkins,** B SC, A M I E E, of the Electrical Engineering Section of B I S R A's Plant Engineering Division at Battersea. Both these new appointments are operative from July 1, 1958.

Mr Carlisle graduated at Queen's University, Belfast (College of Technology), in electrical engineering, and later continued his studies at the College, being granted the degree of M SC in 1942. During the course of higher study he was appointed a temporary lecturer in radio and radio-physics at the college. In 1942 he joined the staff of the Director of Scientific Research, Admiralty, and was stationed for four years on H M S *Excellent*, Portsmouth, where he was engaged on the development and trials of radar and gun-control equipment, being particularly concerned with the development of electrical predictors. He joined B I S R A in 1946, and in 1947 was appointed head of the Instrument Section of the Physics Department, where he was particularly concerned with the development of new measuring and control systems for furnaces, hot strip width measuring techniques and automatic strip gauge control systems.

Mr. Jenkins, born in Swansea, graduated in Electrical Engineering at the University College of Swansea in 1943. After serving as an electrical engineering officer with the R A F he joined the British Thomson-Houston Co Ltd, of Rugby. Subsequently joining McLellan & Partners, consulting engineers, he began a close association with the steel industry through this firm's connection with the building of new plants at Trostre, Velindre and Ebbw Vale. He first joined the Association in 1952, and has been closely associated with developments in tandem rolling, automatic control, translator devices and programming.

Mr F. Moore has been appointed deputy chief engineer of Steel, Peech & Tozer, a branch of the United Steel Companies Ltd. Mr Moore joined United Steel as an engineering apprentice at the Appleby-Frodingham branch in 1922. He has been at Steel, Peech & Tozer since 1946 and was assistant mechanical maintenance superintendent until his new appointment.

William Jessop & Sons Ltd and their associated company J. J. Saville & Co Ltd announce that, following the death of Mr F. Briggs, F C I S, the late secretary of these companies, **Mr D. Milne,** C A, has been appointed as secretary. **Mr J. V. Gregory** has been appointed as assistant secretary.

At the annual general meeting of the Aluminium Development Association, last month, **Mr S. E. Clotworthy** was elected president of the Association for 1958/9. Dr Maurice Cook (chairman, I C I Metals Division) was elected vice-president.

Mr Clotworthy, who is managing director of Northern Aluminium Co Ltd, has been with that company for over 30 years and has contributed largely to its growth from virtually its first beginnings. He has served in various capacities on many of the leading organizations of the metallurgical world; the outbreak of war saw him seconded to the Ministry of Aircraft Production, first as deputy director of Sheet and Strip and then as deputy controller

Mr S. E. Clotworthy

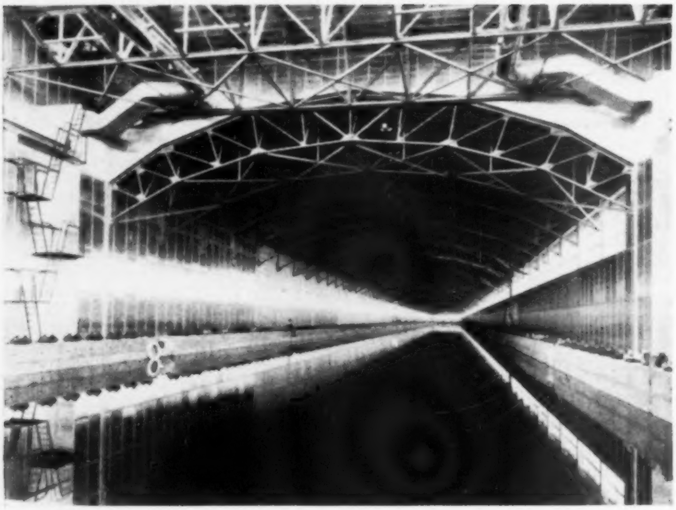
of light metals production. From 1942 to 1946 he was general operating superintendent of Northern Aluminium Company Ltd—and largely responsible for the establishment of Rogerstone Works—and in 1946 became a director and general sales manager of the Company; he was appointed managing director in April, 1957. Mr. Clotworthy is a member of the Institution of Electrical Engineers and of the Institute of Metals, and is an Associate Fellow of the Royal Aeronautical Society.

Lord Dudley G. Gordon, chairman of the Hadfield Group of Companies, left on April 23 for Canada to begin a tour of North America in connection with the development of the companies' export business.

While in Canada he will be able to visit the subsidiary companies of the group and see the considerable extensions that have been made to the plants. Discussions with important customers of both Hadfields and Millspaughs are included in the programme and he will be able to go over plants where the products of these Companies are being used.

While at Ottawa, Lord Dudley will be the guest of the Governor General, His Excellency The Right Honourable Vincent Massey, C H.

The tour also includes a visit to the United States of America.



Ship-testing tank at Feltham showing the aluminium roof structure which covers an area 1,460 ft long by 67 ft wide. The aluminium roof is supported by a steel structure

world's finest servo test equipment.' The equipment is destined for guided missile work.

£250,000 order for locomotive gearboxes

A contract worth nearly a quarter of a million pounds has been placed by North British Locomotive Co Ltd, of Glasgow, with the General Gear Division, Park Works, of David Brown Industries Ltd, for axle mounted gearboxes. This follows the placing of an order by British Railways for 52 main-line diesel/hydraulic locomotives, the largest single order so far to be received by one company for locomotives and a substantial part of the total of 147 locomotives of this type ordered under the railway modernization programme.

These 52 units, each of 1,000/1,100 b h p, represent the first major instalment of a scheme for replacing steam by diesel traction in British Railways' Western Region, on passenger and freight services between Newton Abbot and Penzance, and many of the through trains between Paddington and Bristol and the West of England.

British Oxygen extend Corby factory

British Oxygen Gases Ltd are carrying out extensions to their factory at Corby, Northamptonshire. A new equipment sales store is being erected, together with a medical gas filling shop and stores, an oxygen filling dock, a cylinder test shop and a garage for 17 vehicles.

Occupying an area of 7,200 sq ft, the buildings are estimated to cost about £45,000. It is anticipated that work will be completed by the end of this month.

Agents for Drage instruments

Short & Mason Ltd, 280 Wood Street, Walthamstow, London, E 17, has recently signed an agreement with Aktiengesellschaft Chemisches Institut Dr A. G. Epprecht, Zurich, whereby it will act as sole agent in Great Britain for the range of Drage instruments.

An instrument application department has been set up to deal with enquiries and advise on the use and installation of the instruments which include torsional viscometers and rheometers, also plant assemblies for automatic control of viscosity.

Aluminium roof structure at Feltham

The roof structure of the ship-testing tank building at Feltham is believed to be one of the longest built in aluminium. The roof consists of 98 curved roof trusses with a span of 67 ft and covers an area 1,460 ft long by 67 ft wide. The fabrication of this structure was undertaken by Head Wrightson Aluminium Ltd, a subsidiary of Head Wrightson & Co Ltd, for the Ministry of Works.

The temperature in the testing-tank building is kept at a constant figure of 70°F and the highly humid atmosphere resulting in heavy condensation in the roof members presented corrosion and maintenance problems, and these considerations coupled with loading restrictions dictated the use of aluminium as the most suitable material.

The roof is supported by a steel structure supplied by Head Wrightson Teesdale Ltd and the building is a good example of a composite construction in which approximately 105 tons of aluminium were used. The aluminium trusses and lattice girders were fabricated in very large sections so that work on the site and erection time could be cut to a minimum. Mild-steel site bolts were heavily sheradized and over 86,000 aluminium rivets were driven during the construction of the roof members.

The plates and section were supplied by the British Aluminium Co Ltd, I C I, Metal Division, and T I Aluminium Ltd.

N P L open days

The National Physical Laboratory held its annual open days this month on May 14 and 15 when the Laboratory was on show to over 4,000 guests from industry, universities and government departments.

There were about 200 exhibits of N P L work on display, many for the first time. Highlights included diffraction gratings for automatic machine-tool control, made by a new photographic technique; a computer which, like a human being, learns from past experience; and the technique of thermochemical measurements of extremely high accuracy which, for example, helped to explain the Windscale incident.

The Institute of Metals Medal in Platinum has been awarded to **Professor Emeritus Robert Salmon Hutton,** M A, D SC, in recognition of his outstanding work in connection with the science and practice of non-ferrous metallurgy.

Robert Salmon Hutton was born in London in 1876 and educated at Highgate School and Blundell's School, Tiverton. In 1894 he went to Manchester to study chemistry at Owens College, gaining a first-class Honours degree in 1897. He then spent about three years carrying out research.

In 1900 Hutton returned to Manchester, where he remained until 1908 as Lecturer in Electrometallurgy at the Victoria University. He received the D Sc degree of Manchester University in 1905. With the late Sir Joseph Petavel, he carried out an extensive investigation with an electric furnace at high pressures. It was at this time that Hutton invented the electric-furnace method of melting silica and assisted in its industrial exploitation.

In 1908 he resigned his University appointment to join William Hutton & Sons Ltd, manufacturing silversmiths and cutlers.

In 1921 he was appointed first director of the British Non-Ferrous Metals Research Association. He returned to academic life when, in 1932, he was appointed first Goldsmiths' Professor of Metallurgy in the University of Cambridge. Here he supervised an extensive investigation for the Goldsmiths' Company into the tarnishing of silver and the possibilities of preventing it.

Since his retirement from the Chair at Cambridge in 1945, Professor Hutton has been actively concerned with higher technological education. In addition, he was, from 1945 to 1952, temporary director of research and later a member of the Governing Council of the Design and Research Centre for the Gold, Silver and Jewellery Industries.

He has been active in the affairs of a number of scientific societies. He was an Original Member of the Institute of Metals and served continuously on its Council from 1909 to 1926 (as Vice-President from 1927 to 1936). He was subsequently made a Fellow, in recognition of his services to the Institute. He was a Founder Member of the Faraday Society and served on its Council from 1906 to 1914. He was also a Founder Member of the American Electrochemical Society, and in 1924 of A S L I B (Association of Special Libraries and Information Bureaux), of which he later became President (1942-44).

The Rosenhain Medal has been awarded by the Institute of Metals to **Dr John Herbert Hollomon,** in recognition of his outstanding contributions to knowledge in the field of physical metallurgy.

Dr John Herbert Hollomon is manager of the Metallurgy and Ceramics Research Department of the General Electric Research Laboratory, Schenectady, New York.

He received his Bachelor and Doctor of Science degrees from Massachusetts Institute of Technology. After a period of service on the faculty of Harvard University, he served in the U S Army from 1942 to 1946, attaining the rank of major.

In 1946 Dr Hollomon joined the General Electric Research Laboratory and was appointed assistant manager of the Metallurgy Research Department before being advanced to manager.

His professional honours include the Rossiter W. Raymond award of the American Institute of Mechanical Engineers in 1946, and the Alfred Noble award of the Combined Engineering Societies, 1947, for a paper entitled, 'The Mechanical Equation of State.' In September, 1951, he was one of five U S physicists elected as participants in the Ninth International Solvay Physics Conference on solid-state physics at Brussels. In January of 1955, Dr Hollomon was chosen by the U S National Junior Chamber of Commerce as one of America's ten outstanding men of 1954.

Mr Robert Carr, M P, has accepted the invitation of the Board of Directors of John Dale Ltd to become chairman of the parent company of their group. Mr Carr has relinquished his appointment as Parliamentary Secretary to the Ministry of Labour and National Service.

Joining John Dale Ltd in 1938, Mr Carr worked in the moulding and tube departments. A period as shift foreman in the billet and ingot foundry in 1939 was followed by experience as a radiologist, and in 1945 he became John Dale's metallurgist, a post he held until 1948 when he was appointed director in charge of Research and Development.

Mr. H. Haworth has been appointed planning and progress engineer at the Templeborough works of Steel, Peech & Tozer, a branch of the United Steel Cos. Ltd. He succeeds the late Mr. H. Lawson.

Mr. J. Strong, a director of the British Oxygen Co., has relinquished his appointment as chairman of Quasi-Arc Ltd. on being appointed chief executive director of British Oxygen Gases Ltd.

On appointment as finance manager, **Mr. A. D. Smart** relinquished the post of secretary, the British Oxygen Co. Ltd., and was succeeded therein by **Mr. B. R. D. Clark.**

New instrument company

A new instrument company, Research & Control Instruments Ltd, Instrument House, 207 King's Cross Road, London, W.C.1 (Terminus 8444) is the sole distributor in the U K for the electronic instruments and scientific equipment hitherto marketed by Philips Electrical Ltd (Research and Control Instruments Division).

The new company assumes full responsibility for the maintenance of existing Philips equipment and its field staff will be supported from a new Service Department and Stores located at 49 Temperley Road, Balham, London, S W 12 (Battersea 9166/7). It will also be the distributor in Great Britain for the industrial X-ray equipment manufactured by C. H. F. Müller A.G., Hamburg, and for Norelco (U S A) X-ray Diffraction and Spectrographic equipment.

Research & Control Instruments Ltd has also been appointed sole distributor for the sale and servicing of Mullard electronic measuring instruments and electrochemical apparatus in the U K. New to the British market and also to be handled by the company will be the electronic instruments made by Elektro-Spezial A.G., of Hamburg.

Italy orders British electronic equipment

Winston Electronics has received another order for over £70,000 from Italy for electronic equipment, which includes spectrum analysers and highly stabilized decade oscillators.

Corrigendum

We regret that in the April issue **Prof A. G. Quarrell** was described as pro-chancellor of the University of Sheffield. Prof Quarrell will, in fact, become pro-vice-chancellor of the University.

Classified Advertisements

FIFTEEN WORDS for 7/6d. (minimum charge) and 4d. per word thereafter. Box number 2/6d., including postage of replies. Situations Wanted 2d. per word.

Replies addressed to Box Numbers are to be sent, clearly marked, to Metal Treatment and Drop Forging, John Adam House, John Adam Street, London, W.C.2.

SITUATIONS VACANT

ICI

GENERAL CHEMICALS DIVISION

has a vacancy for a

METALLURGIST

for Technical Sales Service work in its Heat Treatment Section, near Birmingham. The successful candidate will be required to advise customers on problems relating to the treatment of ferrous metals in molten salt baths, and allied matters.

Applications will be welcomed from men between the ages of 25 and 33, preferably with a metallurgical degree, A.I.M. or L.I.M., and engineering works' experience. The position carries a good starting salary, membership of the Staff Pension Fund, and eligibility for the Company's Profit-sharing Scheme. Some help may be given to married men towards housing and removal expenses in approved cases.

Please apply in writing, quoting Ref. HTM 64 and giving brief tabulated details of age, qualifications and experience to: *Staff Manager, Imperial Chemical Industries Limited, General Chemicals Division, Cunard Building, Liverpool* 3.

WEST BROMWICH EDUCATION COMMITTEE

West Bromwich Technical College

Principal: K. G. Lewis, M SC, F I M, F R I C, M I PROD E

Applications are invited for the following full-time appointment, duties to commence 1st September, 1958.

Engineering Department

Lecturer in Metallurgy to teach Metallurgy and Chemistry to O N C level. A background of Chemistry, rather than of Engineering, is necessary. Candidates should have a minimum qualification of A I M or equivalent.

Salary

£1,200 × £30—£1,350 per annum.

Forms of application, to be returned to the Principal of the West Bromwich Technical College, may be obtained from the undersigned.

J. H. Turner,
Director of Education,
Education Offices,
Highfields, West Bromwich.

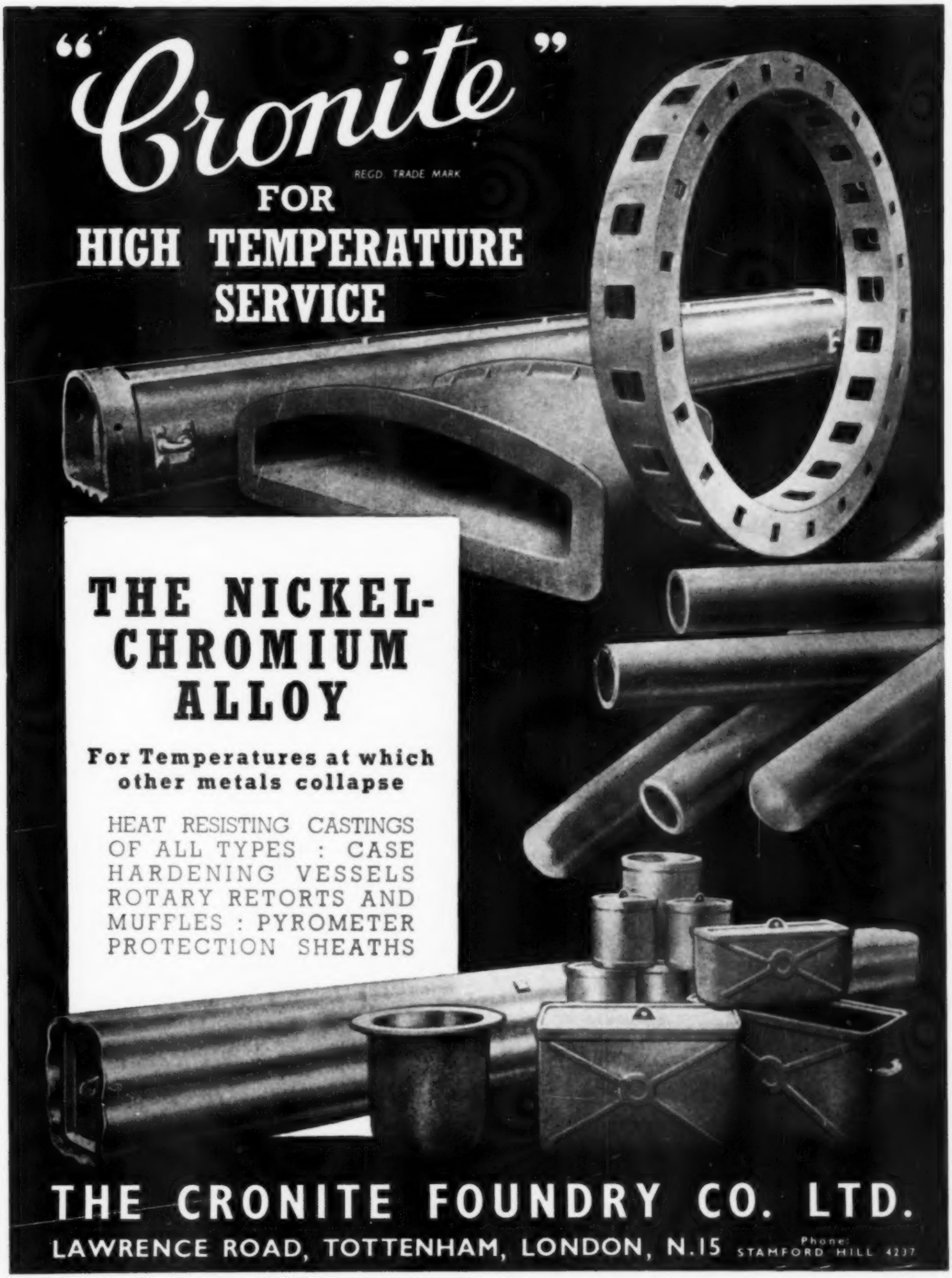
SITUATIONS VACANT—continued

QUALIFIED METALLURGIST required for field service for leading manufacturers of heat-treatment equipment to advise customers and assist them to obtain the best results from their equipment. Good experience of modern industrial heat-treatment practices and problems, and good engineering knowledge essential. Must be prepared to travel at home and abroad at short notice. Progressive opening for keen man with initiative. Write, in confidence, stating age, qualifications, experience and salary required to Chief Metallurgist, Box Q M 104, Metal Treatment and Drop Forging.

MACHINERY FOR SALE

BEAUDRY NO. 3 80-LB. FORGING HAMMER complete with separate anvil. Motor drive 400/3/50. Treadle control. Anvil set at an angle. Stroke adjustable up to 5 ins. Depth of gap 10 ins. Photo. F. J. Edwards Ltd., 359 Euston Road, London, N.W.1.

FOUR HIGH-FREQUENCY GENERATORS, 80 kW. output each. Maker: Phillips Electrical Co. Ltd. Type F 150/1. 200 k.c.p.s. oscillation, complete with all valves. Supporting steel structure, pump, pipe work and control gear, and three Serck air-blast coolers for high-frequency induction furnaces. Equipment has had about 200 hours' use only and is about 3-4 years old. Will sell one set separately; prepared to accept one-quarter of manufacturer's contract price. Equipment can be seen and inspected at Davidsons Engineers (M/c) Ltd., Irkdale Street, Smedley Road, Cheetham Hill, Manchester 8. Tel.: COL. 1610.



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Published by the Proprietors, INDUSTRIAL NEWSPAPERS, LIMITED, John Adam House, 17/19 John Adam Street, Adelphi, London, W.C.2, and Printed in Great Britain by F. J. PARSONS, LTD., London and Hastings.

Metal Treatment and Drop Forging

Vol. 25 : No. 152 MAY, 1958 Price 2/6